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Technical Memorandum No. 33-83

System Capabilities and Development Schedule of the Deep Space Instrumentation Facility, 1964–68

(Revision 1)

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

April 24, 1964

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System Capabilities and Development Schedule of the Deep Space Instrumentation Facility, 1964–68

(Revision 1)

Approved

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April 24, 1964

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FOREWORD

This document presents the estimated capability of the Deep Space Instrumentation Facility (DSIF). Since the capabilities change to meet the changing requirements of the many flight programs, this document should be considered obsolete one year from the date of publication.

Although this document presents the total planned capabilities of the DSIF for the 1964–68 period, the full capability may not be available for any particular project because of the requirements of other programs.

This document supersedes Technical Memorandum No. 33-83 published March 2, 1962.

II. STATION GEOMETRY AND COVERAGE

The locations of the Deep Space Stations have been selected to be approximately 120 deg apart in longitude and between 40 deg N and 40 deg S latitude, so that a spacecraft which is more than 10,000 miles away from the Earth will be under continuous surveillance. The locations of all the stations and their antennas are given in Table 1. Area maps, station maps and pictures and building layouts for the existing Deep Space Stations, and a picture of the Spacecraft Monitoring Station are presented in Figs. 1 through 19.

The loci of subvehicle points, with 0-deg horizon mask angles employing the 85-ft-diameter polar-mount (hour angle and declination coordinates) antennas at Goldstone, Johannesburg, and Woomera are shown in Fig. 20; Fig. 21 shows the loci of subvehicle points for an 8-deg horizon mask for Goldstone and the two stations under construction at Madrid and Canberra. Figures 20 and 21 indicate the field of view of each polar-mount Deep Space Station as a function of vehicle altitude as well as the region of overlapping coverage. The actual ground masks and antenna prelimits of the existing polar-mount antennas are shown in Figs. 22 through 24. Ephemeris data may be plotted directly onto these station charts in either hour angle (HA) and declination (Dec) coordinates or in azimuth (Az) and elevation (El) coordinates. Copies of these coordinate charts are available from the Jet Propulsion Laboratory.

In the DSIF, it is planned to construct large, 210-ft-diameter parabolic antennas and to locate one of these antennas at each of three selected Deep Space Station sites. The present schedule calls for the first large antenna to be installed at Goldstone by January 1966, the second near Madrid in 1967, and the third near Canberra in 1967. These antennas will be constructed with altazimuth mounts but will employ a Master Equatorial to read out in polar-mount coordinates and will have elevation limits of approximately 5 deg. The estimated coverage of the 210-foot altazimuth-mount antenna at Goldstone is shown in Fig. 25.

Table 1. Station location[a]

Location	Antenna diameter, ft	Station identification number	Geodetic latitude	Geodetic longitude	Height above mean sea level, meters[b]	Geocentric latitude	Geocentric longitude	Geocentric radius, km
Goldstone, Calif. (Pioneer)	85	11	35.38950N	243.15175E	1037.5	35.20805N	243.15080E	6372.0639
Goldstone, Calif. (Echo)	85	12	35.29986N	243.19539E	989.5	35.11861N	243.19445E	6372.0449
Goldstone, Calif. (Mars [c,d])	210	13	35.24772N	243.20599E	1213.5	35.06662N	243.20505E	6372.2869
Goldstone, Calif. (Venus [e])	85	14	35.42528N	243.12222E	1160	35.24376N	243.12127E	6372.1594
Woomera, Australia	85	41	31.38314S	136.88614E	144.8	31.21236S	136.88614E	6372.5481
Canberra, Australia [c,d]	85	42	35.40111S	148.98027E	654	35.21962S	148.98027E	6371.6816
Johannesburg, S. Africa	85	51	25.88921S	27.68570E	1409.1	25.73876S	27.68558E	6375.5504
Madrid, Spain [c,d]	85	61	40.429 N	355.751 E	800	40.334 N	355.751 E	6374.37
Spacecraft monitoring, Cape Kennedy, Fla. [f]		71	28.48713N	279.42315E	4.0	28.32648N	279.42315E	6373.2874

[a]The parameters are referenced to the NASA Earth Model Spheroid with an equatorial radius of 6378.165 km and a flattening of 1/298.3.
[b]Measured to the point of intersection of the hour angle axis with the plane of the declination gear on polar mount antennas.
[c]Under construction with estimated completion as follows: Goldstone Mars, January 1966; Canberra, December 1964; Madrid, June 1965.
[d]Tentative location; definite location to be determined after antenna erection.
[e]This station is used normally for engineering and development; on special assignment it may be used in operations.
[f]Temporary location of present L-band station.

I. INTRODUCTION

The Deep Space Instrumentation Facility (DSIF) is a precision tracking and communications system capable of providing command, control, tracking, and data acquisition from spacecraft designed for deep space exploration. (As used here, "deep space" means distances from the earth of more than 10,000 miles.) Although it is designed for use in deep space exploration, the DSIF may be used with other types of missions wherein its capabilities can be used to advantage.

The DSIF is comprised of seven[1] Deep Space Stations (two under construction), a launch area spacecraft monitoring station, an intersite communications network, and a DSIF operations control center.

The seven Deep Space Stations are located at longitudes approximately 120 deg apart so as to provide continuous coverage of a spacecraft in deep space. Stations are located at Goldstone, California (one under construction); Woomera, Australia; Johannesburg, South Africa; Canberra, Australia (under construction); and Madrid, Spain (under construction). The Deep Space Stations are equipped with 85-ft-diameter polar-mount reflector antennas which have maximum tracking rates of 0.7-deg per sec. The spacecraft monitoring station is located at Cape Kennedy, Florida, and is presently equipped for L-band frequencies only. The DSIF Operation Control Center is located at the Jet Propulsion Laboratory, Pasadena, California.

The design philosophy of the DSIF is to provide a precision radio tracking system which measures two angles, radial velocity, and range and to utilize this system for two-way communications with spacecraft in an efficient and reliable manner. The DSIF will be improved and modernized to remain consistent with state-of-the-art and project requirements.

The National Aeronautics and Space Administration is the cognizant agency responsible for the DSIF. The Jet Propulsion Laboratory is under contract to NASA for research, development, and procurement relating to the Deep Space Stations, mobile stations, and monitoring stations and for the technical coordination and liaison necessary to establish and operate the DSIF throughout the world. Overseas Deep Space Stations are generally operated by personnel provided by cooperating agencies in the respective countries. The Goldstone stations and the monitoring station are operated by United States personnel.

In addition to their participation in the DSIF, the Goldstone stations are utilized for extensive investigation into space tracking and communication techniques and for the development of new equipment. In most cases, the new equipment will be installed and tested at Goldstone before it is integrated into the DSIF. Once this equipment has been accepted for general use within the DSIF, it is classed as Goldstone Duplicate Standard (GSDS) equipment, which standardizes the design and formalizes the documentation of like items throughout the net.

Operational control of the DSIF during a mission is provided by the DSIF Control Center, which is located in the Space Flight Operations Facility (SFOF) at JPL. The SFOF furnishes trajectory information to the DSIF, reduces the data which the DSIF acquires from the spacecraft, furnishes command and control data to the DSIF for transmission to the spacecraft, and furnishes facilities for the operations control of spacecraft. The DSIF together with the SFOF and the interstation communication is called the Deep Space Network (DSN).

[1]A mobile station is presently located near the Johannesburg Deep Space Station. It is primarily used for early tracking and telemetry data from *Ranger* spacecraft using L-band frequencies. It will be dismantled when all of these spacecraft have been launched, which is expected to be not later than July 1965.

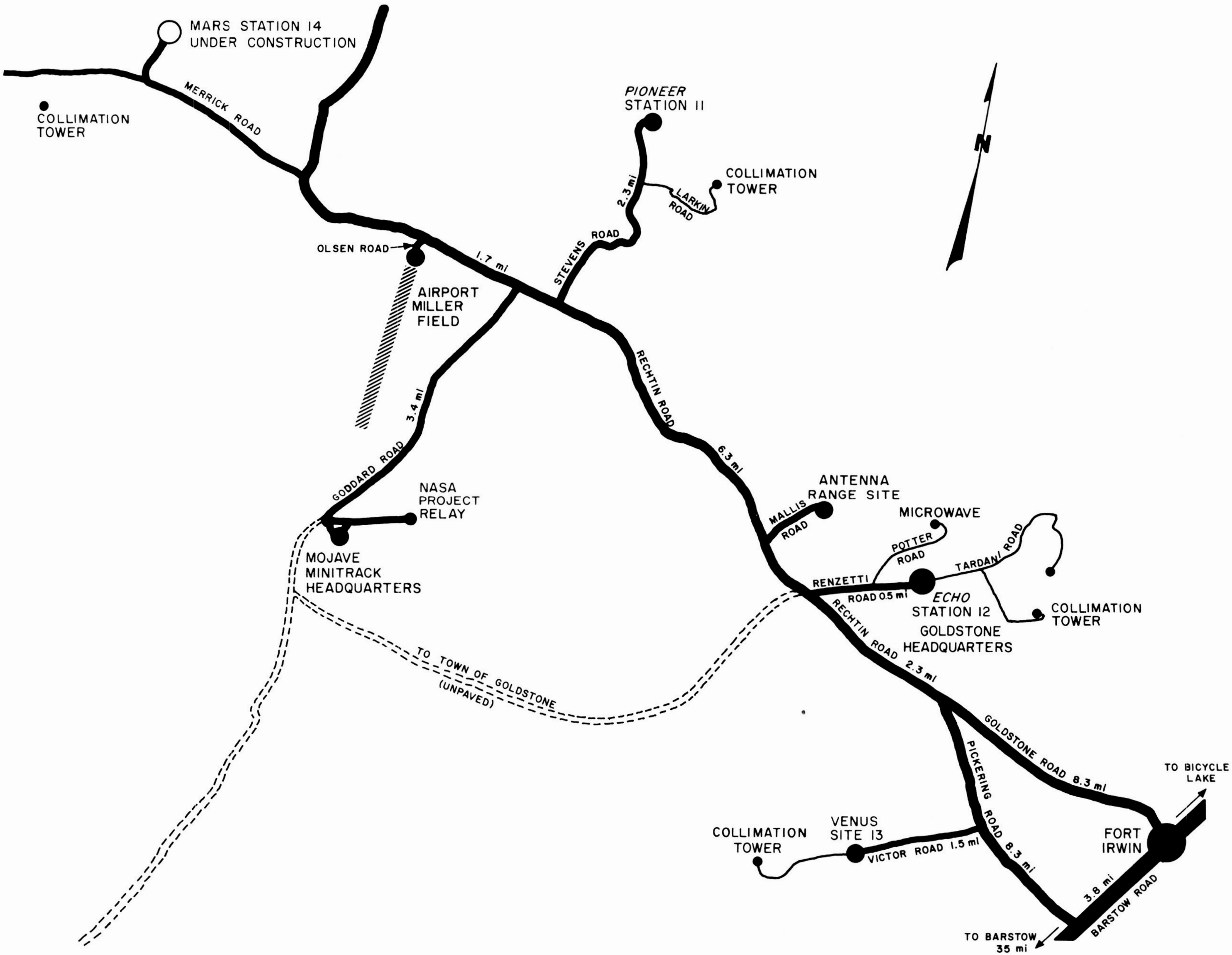
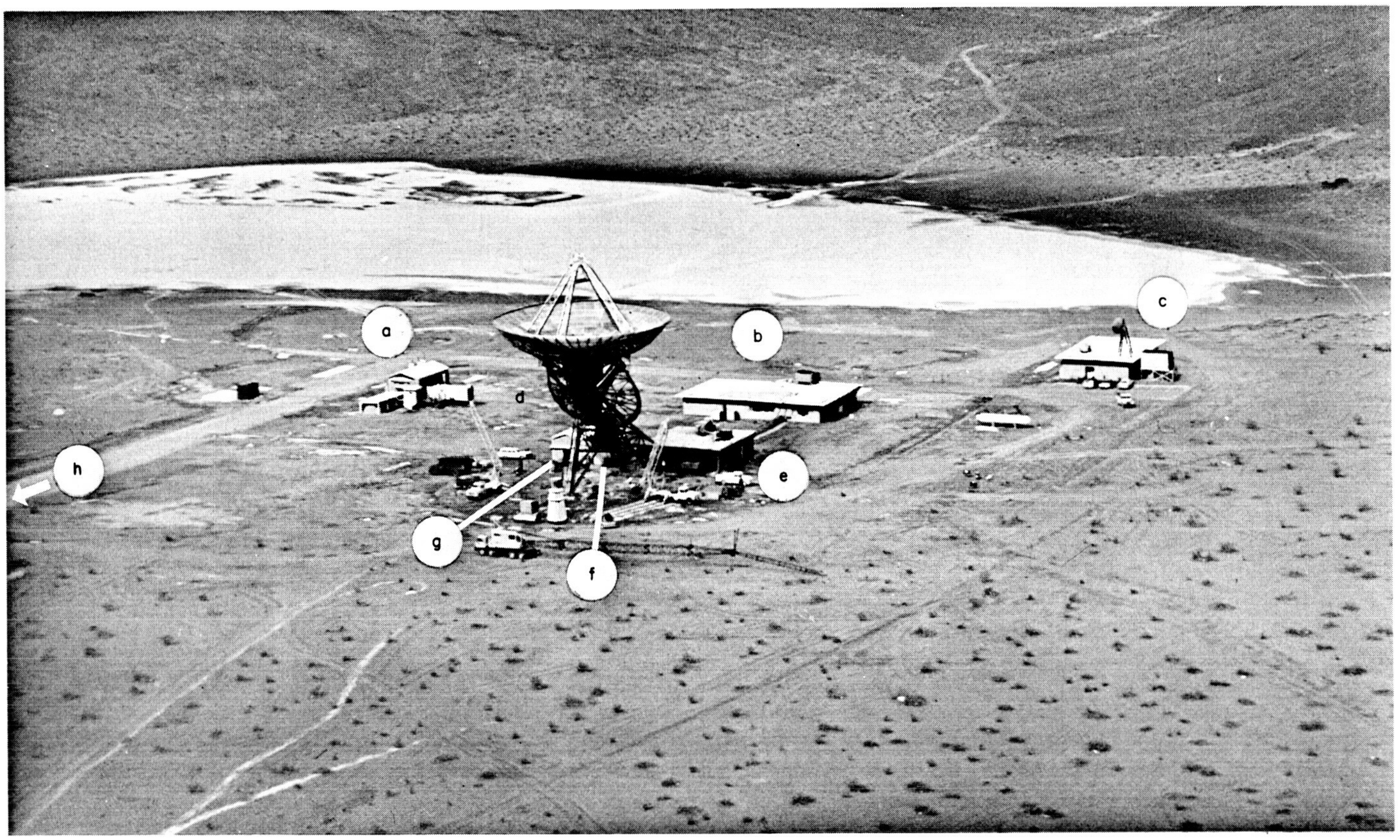
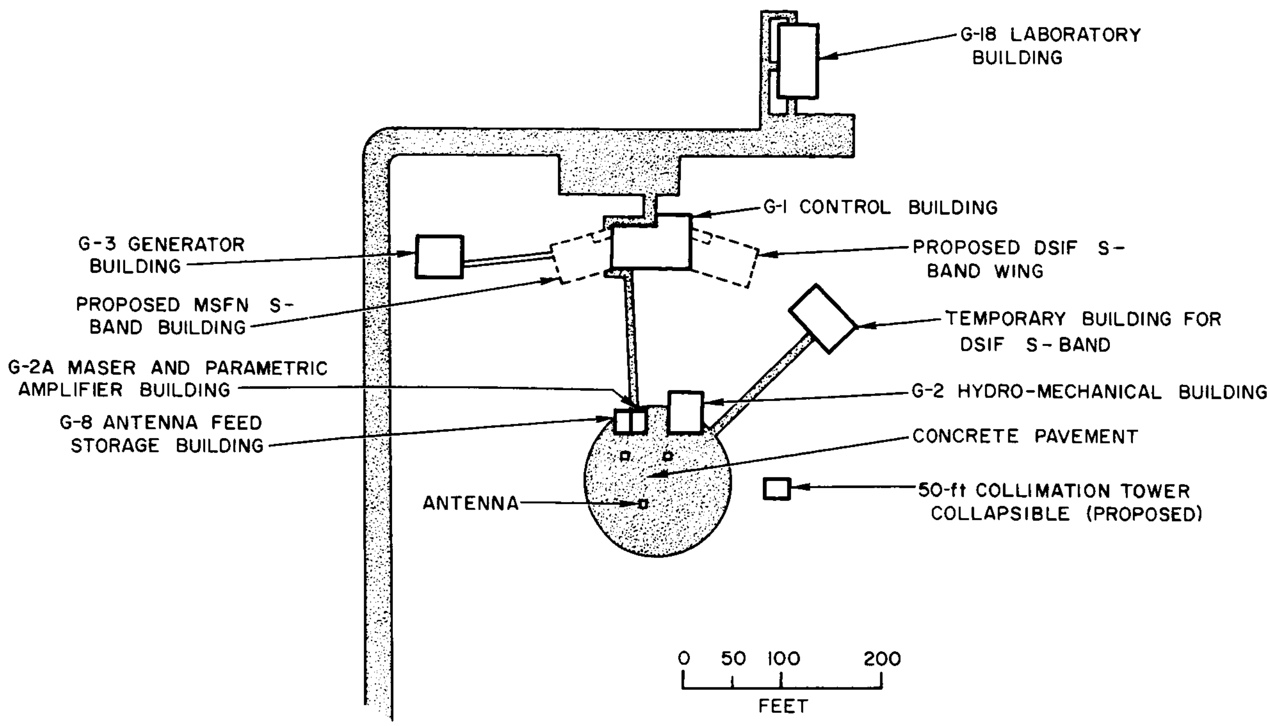


Fig. 1. Area map of Goldstone Stations

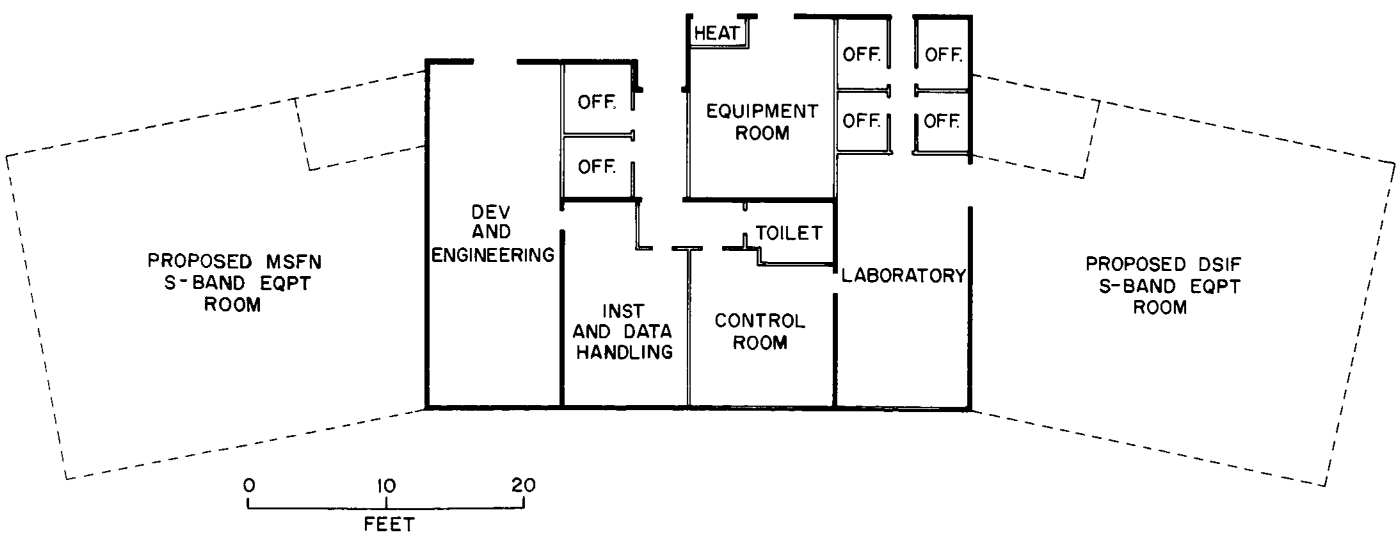


a. GENERATOR BUILDING
b. CONTROL BUILDING
c. LABORATORY BUILDING
d. ANTENNA
e. HYDRO-MECHANICAL BUILDING
f. MASER AND PARAMETRIC AMPLIFIER BUILDING
g. ANTENNA FIELD STORAGE BUILDING
h. GUARD HOUSE

Fig. 2. Goldstone Pioneer Station

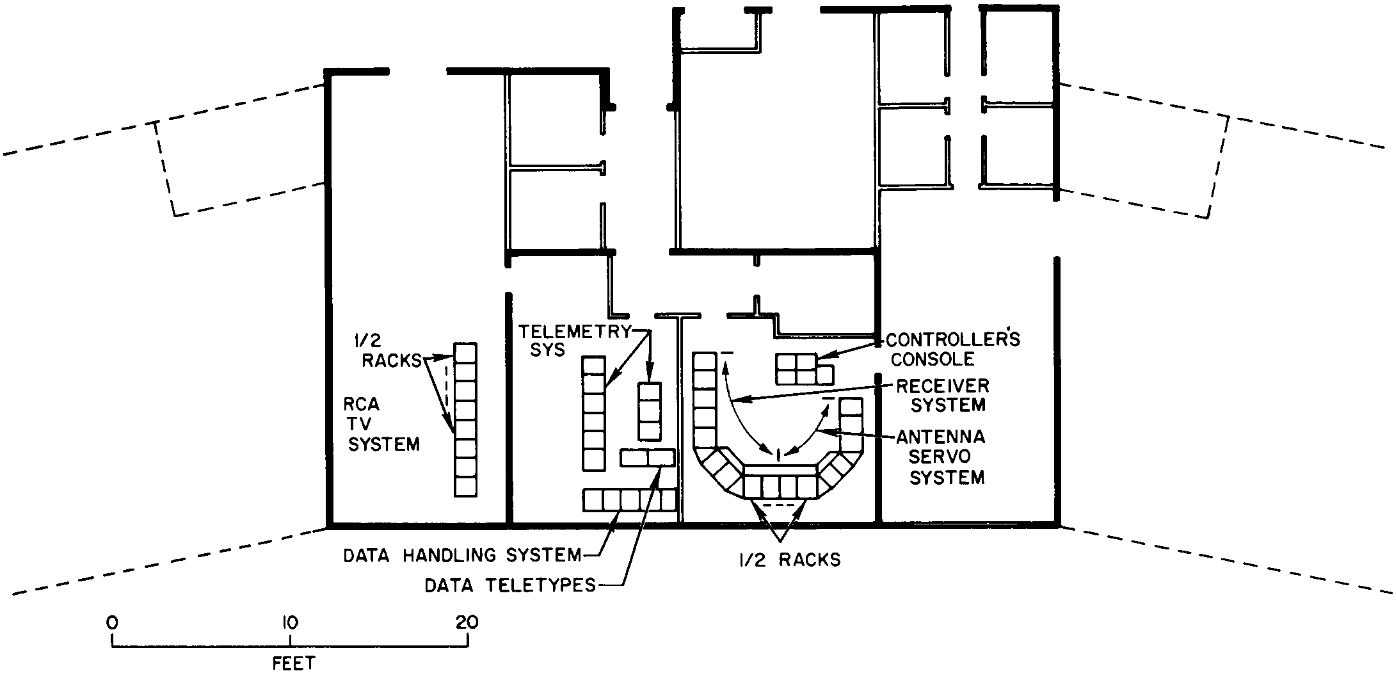


a. STATION MAP

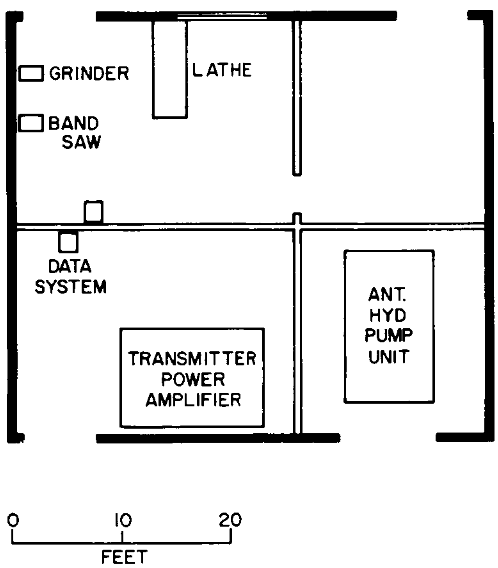


b. CONTROL BUILDING

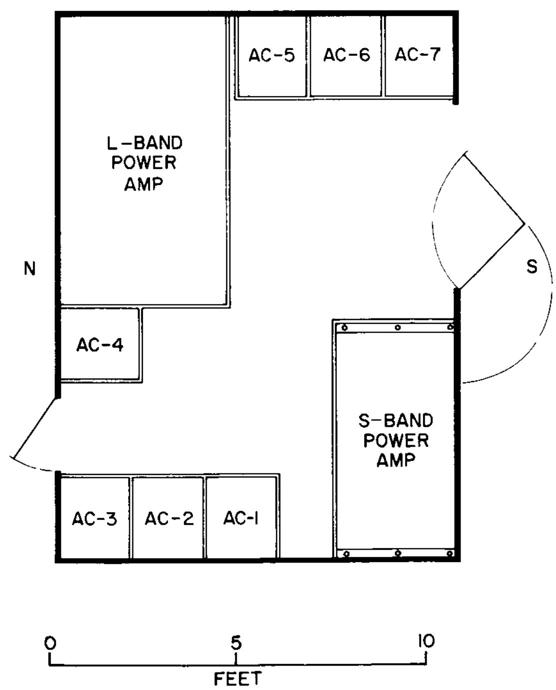
Fig. 3. Goldstone Pioneer Station: station map and control building floor plan



a. CONTROL AND INSTRUMENTATION ROOMS

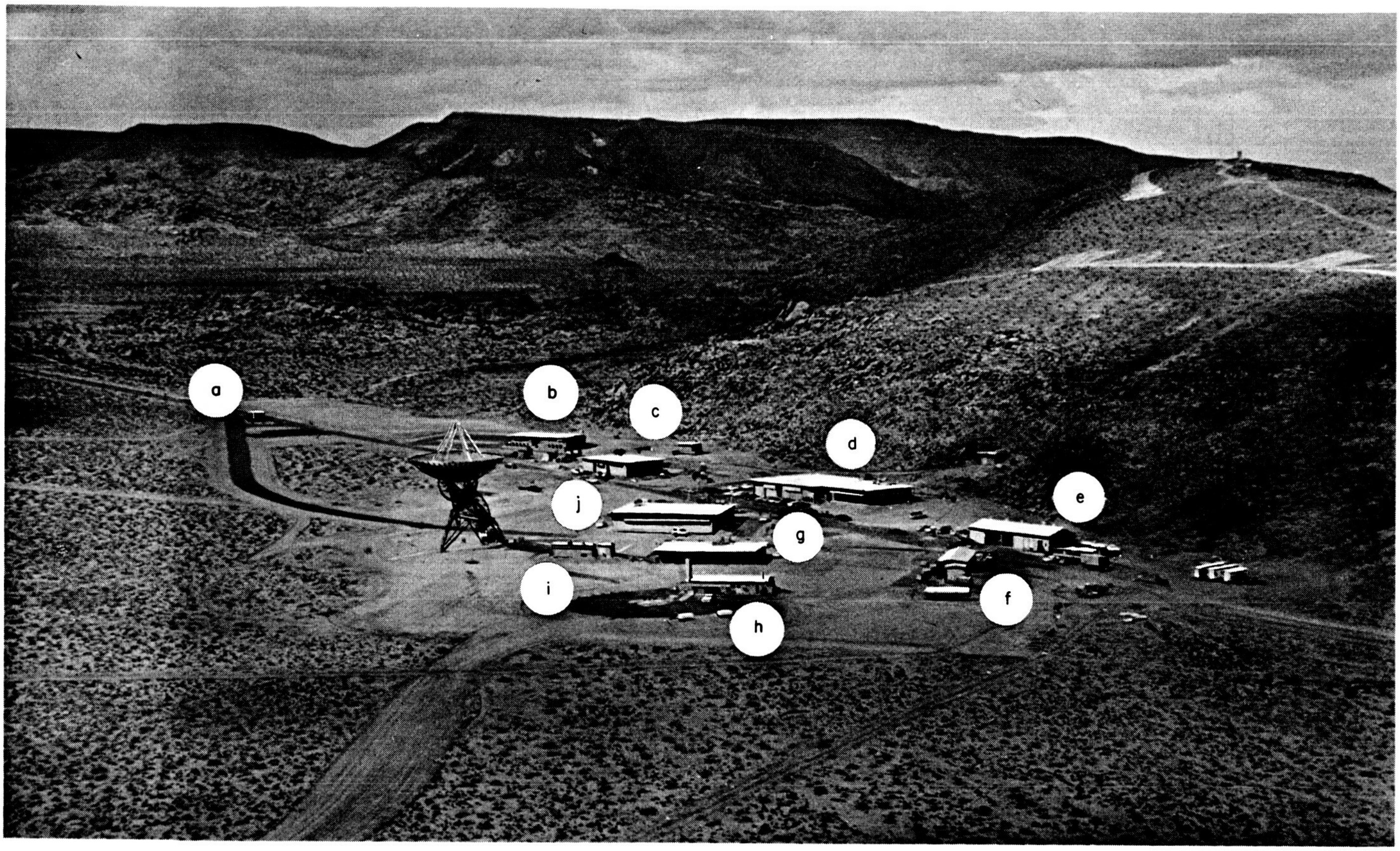


b. HYDRO-MECH. BUILDING



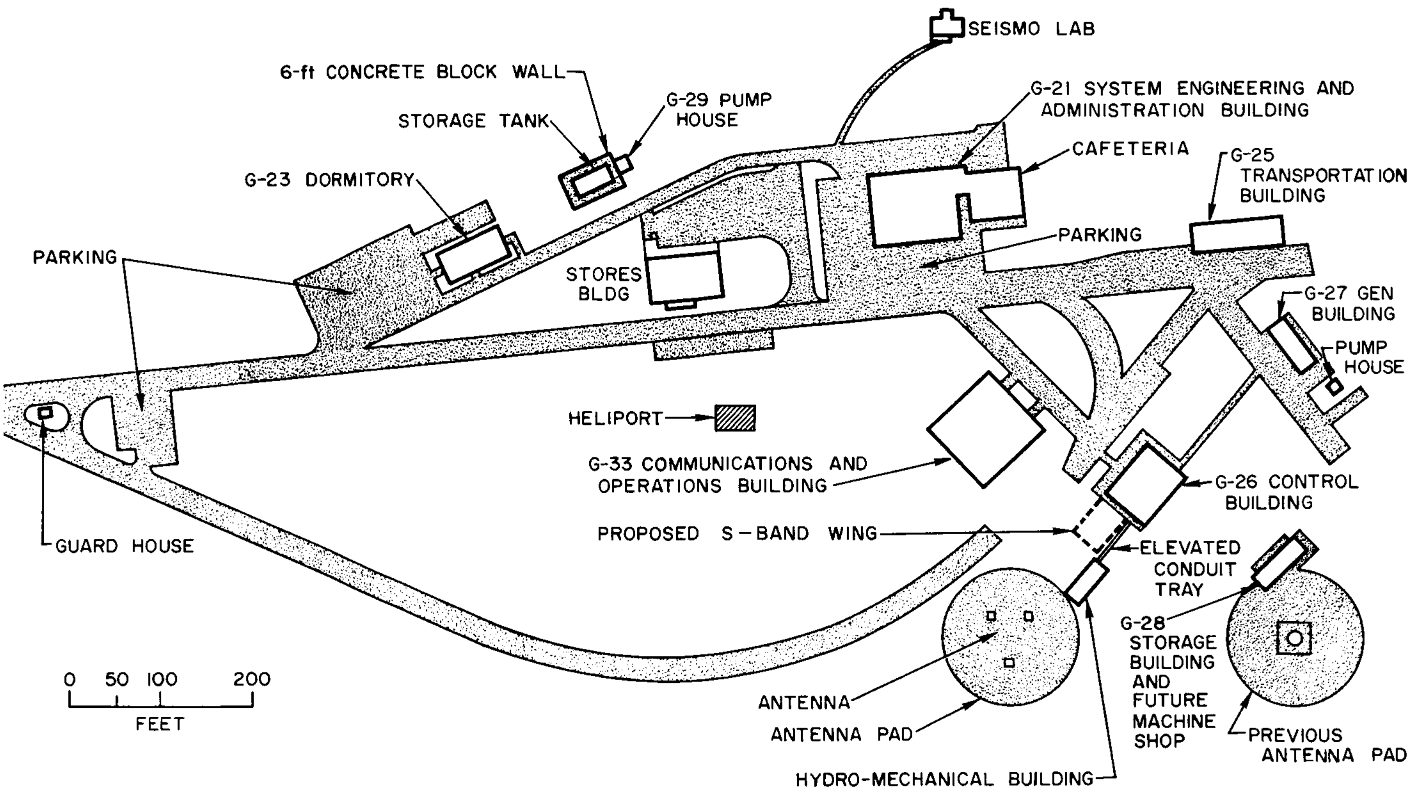
c. ANTENNA CAGE

Fig. 4. Goldstone Pioneer Station: building floor plans and equipment layouts

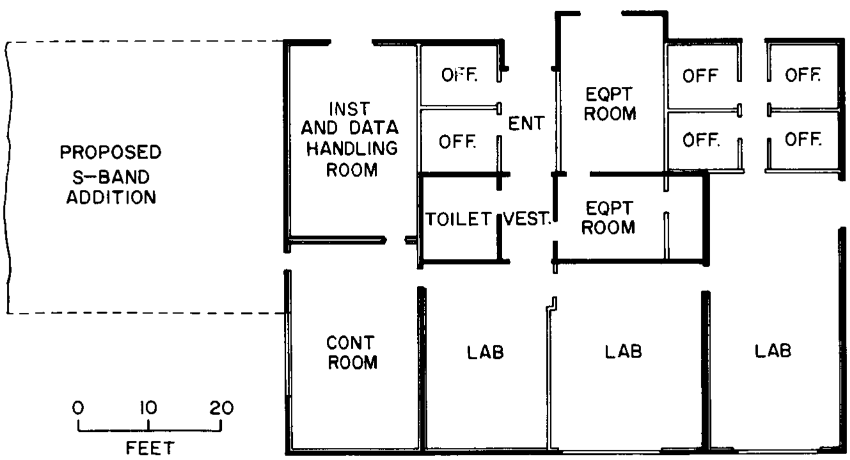


a. GUARD HOUSE
b. DORMITORY
c. WATER STORAGE TANK
d. SYSTEM ENGINEERING, ADMINISTRATION AND CAFETERIA BUILDING
e. TRANSPORTATION BUILDING
f. GENERATOR BUILDING
g. CONTROL BUILDING
h. STORAGE BUILDING AND FUTURE MACHINE SHOP
i. HYDRO-MECHANICAL BUILDING
j. COMMUNICATIONS AND OPERATIONS BUILDING

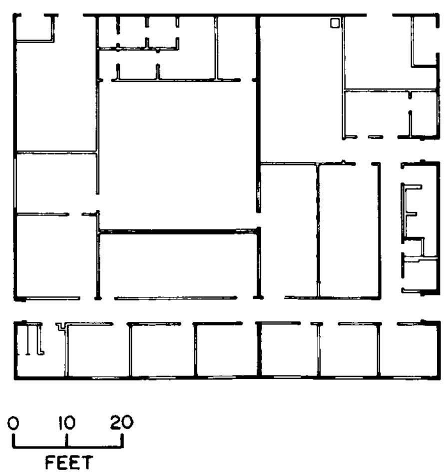
Fig. 5. Goldstone Echo Station



a. STATION MAP

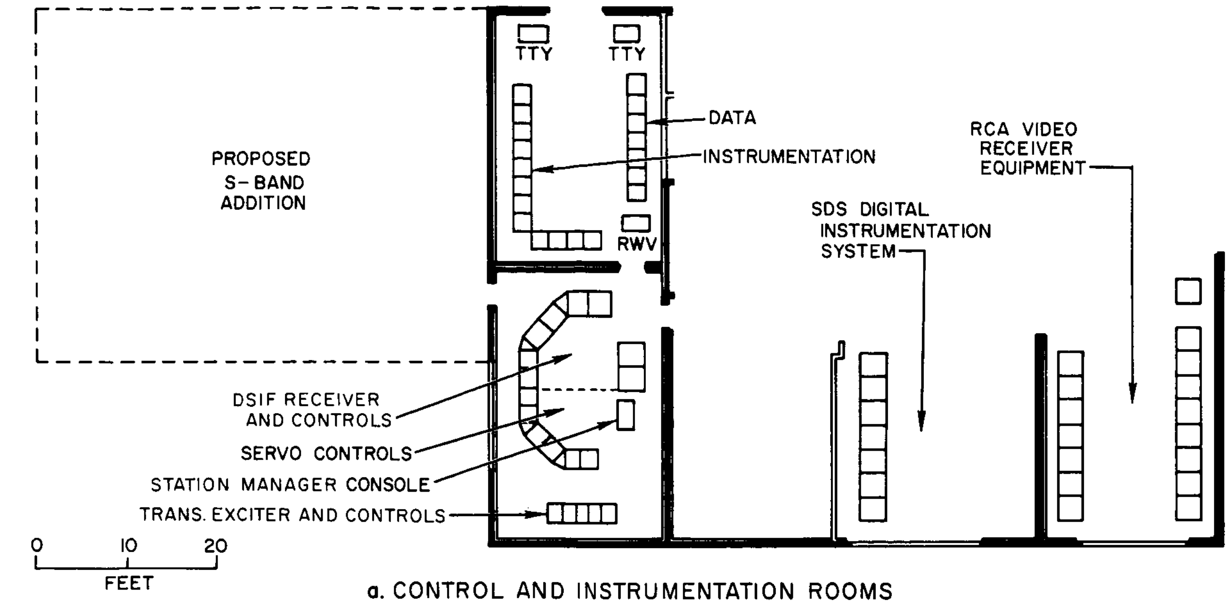


b. G-26 CONTROL BUILDING

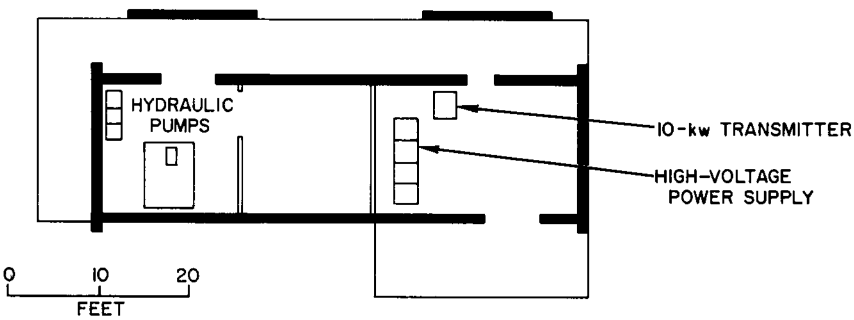


c. G-33 COMMUNICATIONS AND OPERATION BUILDING

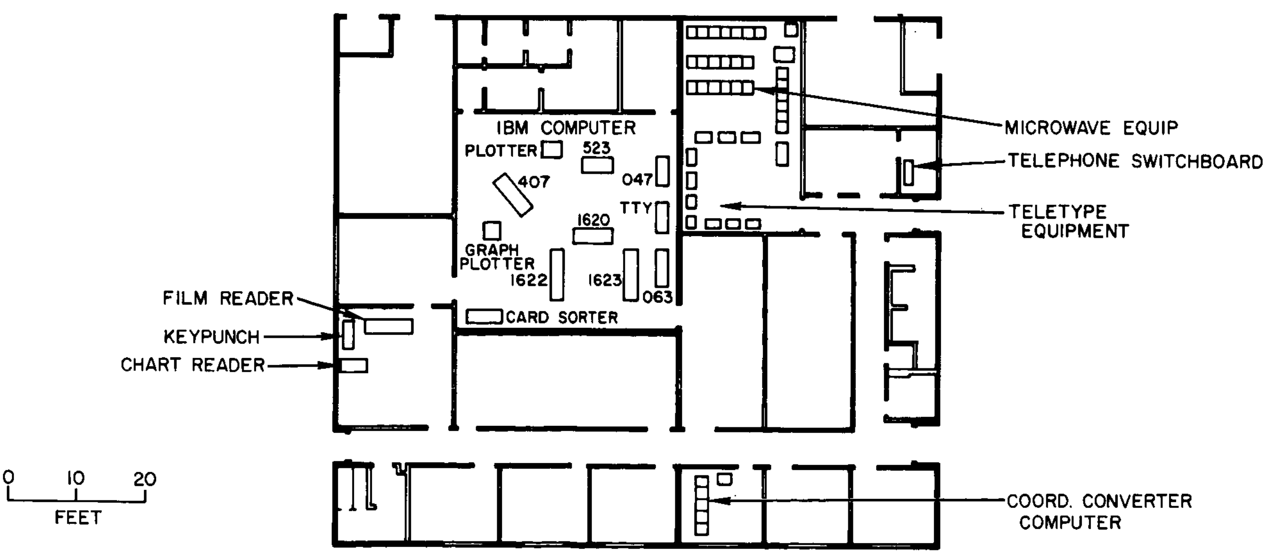
Fig. 6. Goldstone Echo Station: station map and control and communication buildings floor plan



a. CONTROL AND INSTRUMENTATION ROOMS

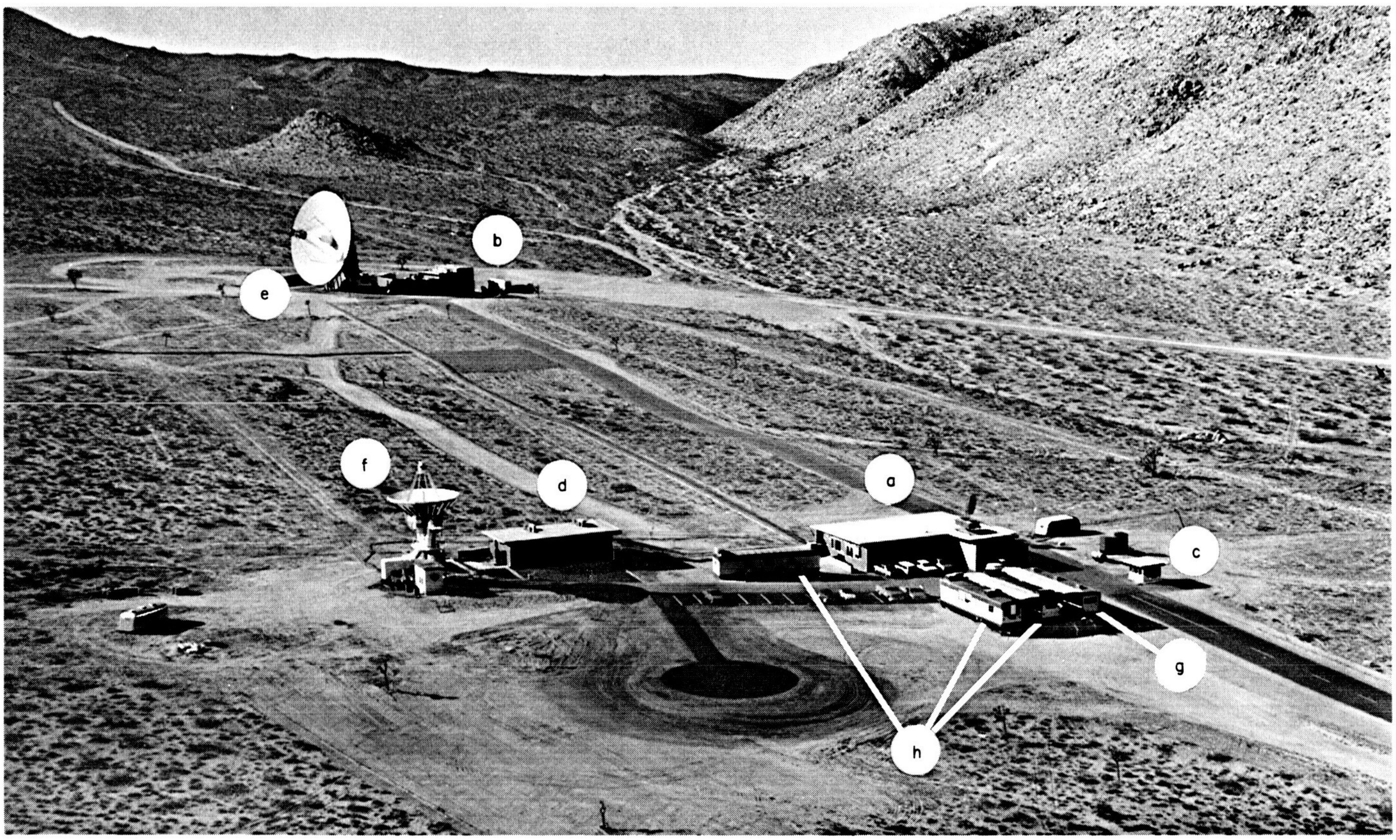


b. HYDRO-MECHANICAL BUILDING



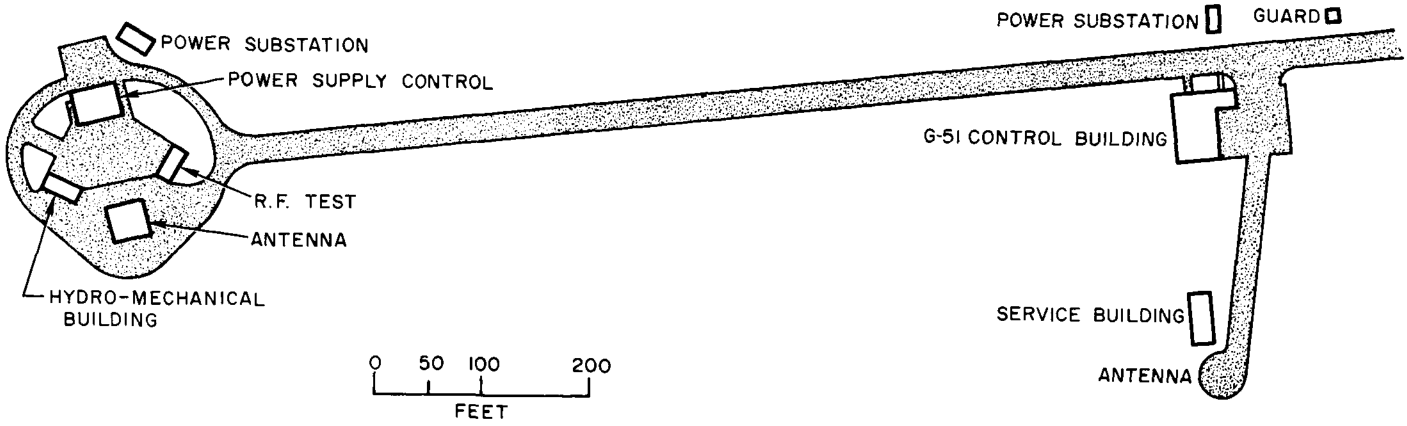
c. G-33 COMMUNICATIONS AND OPERATIONS BUILDINGS

Fig. 7. Goldstone Echo Station: building floor plans and equipment layouts

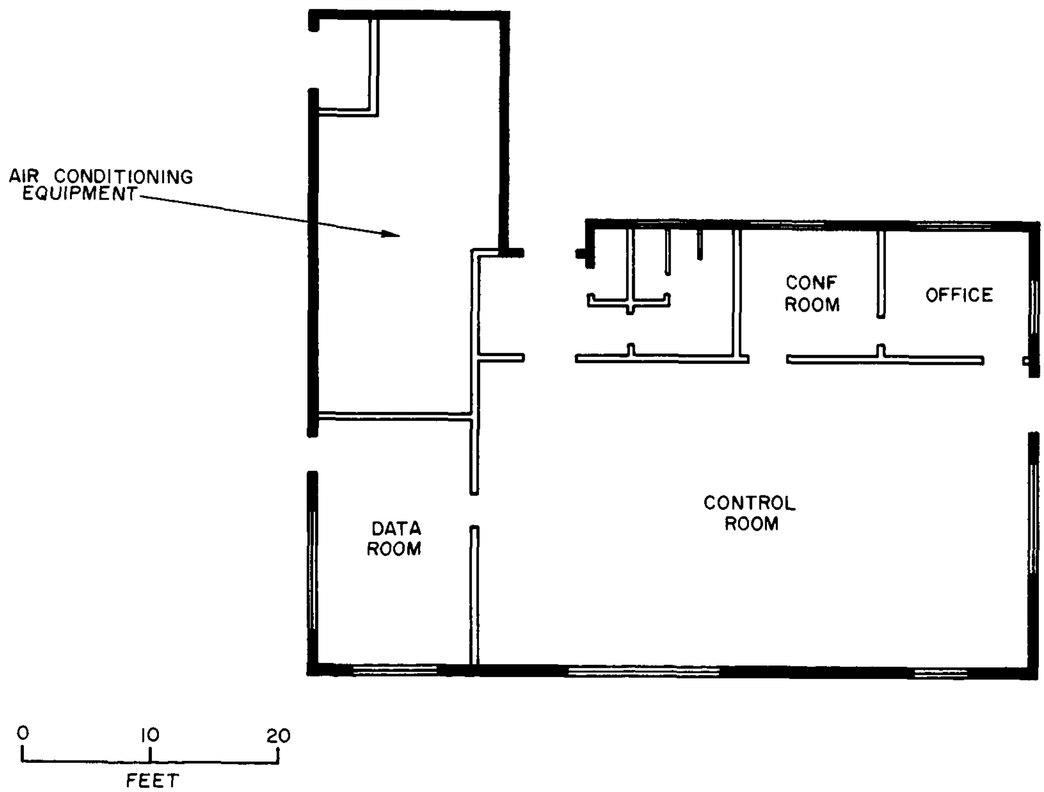


a. G-51 CONTROL BUILDING
b. G-53 FACILITY COMPLEX
c. G-56 GUARD HOUSE
d. G-58 SERVICE BUILDING
e. 85-ft AZ-EL ANTENNA
f. 30-ft AZ-EL ANTENNA
g. OFFICE TRAILER
h. LAB TRAILER

Fig. 8. Goldstone Venus Station

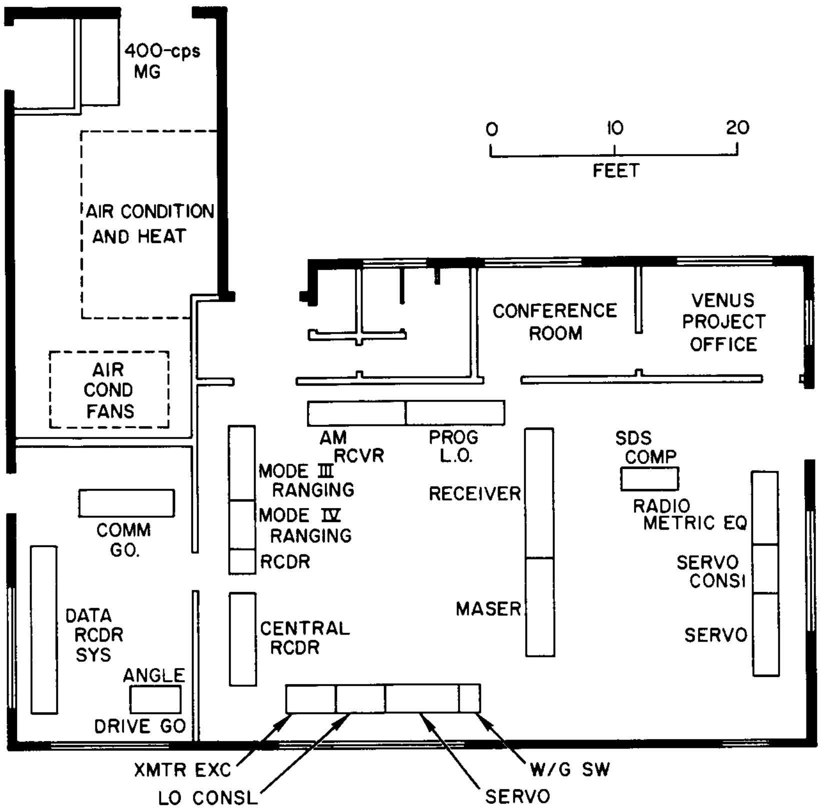


a. STATION MAP

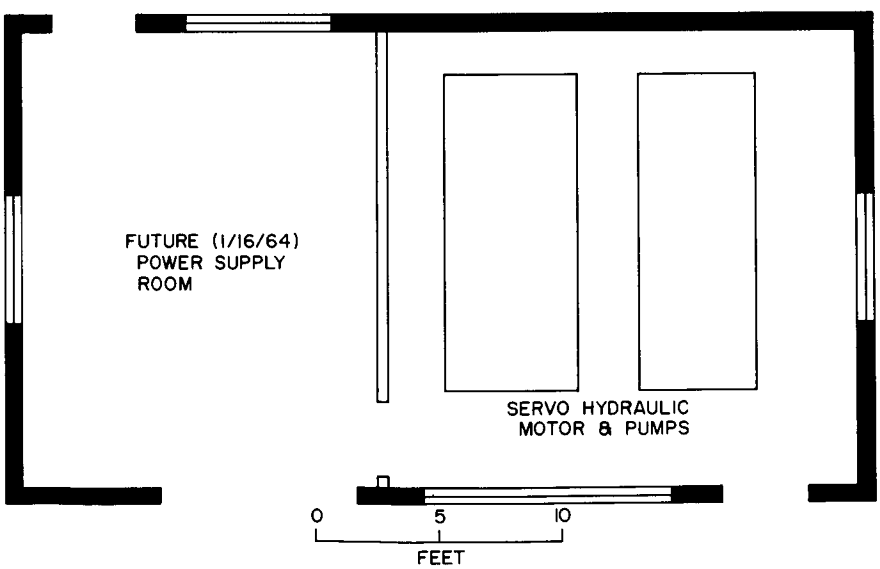


b. CONTROL BUILDING

Fig. 9. Goldstone Venus Station: station map and control building floor plan



a. CONTROL BUILDING



b. G-53 FACILITY COMPLEX BUILDING

Fig. 10. Goldstone Venus Station: building floor plans and equipment layouts

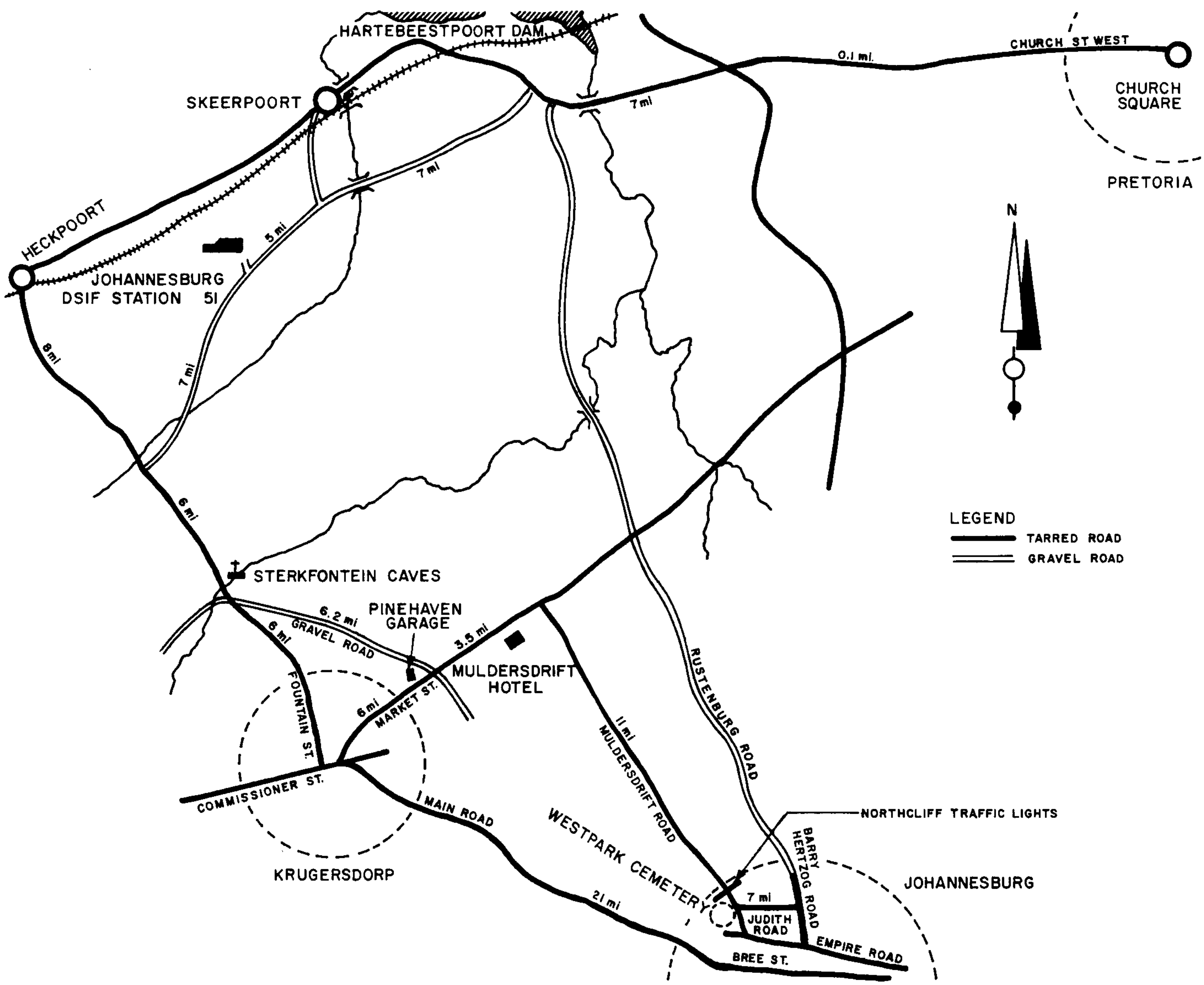
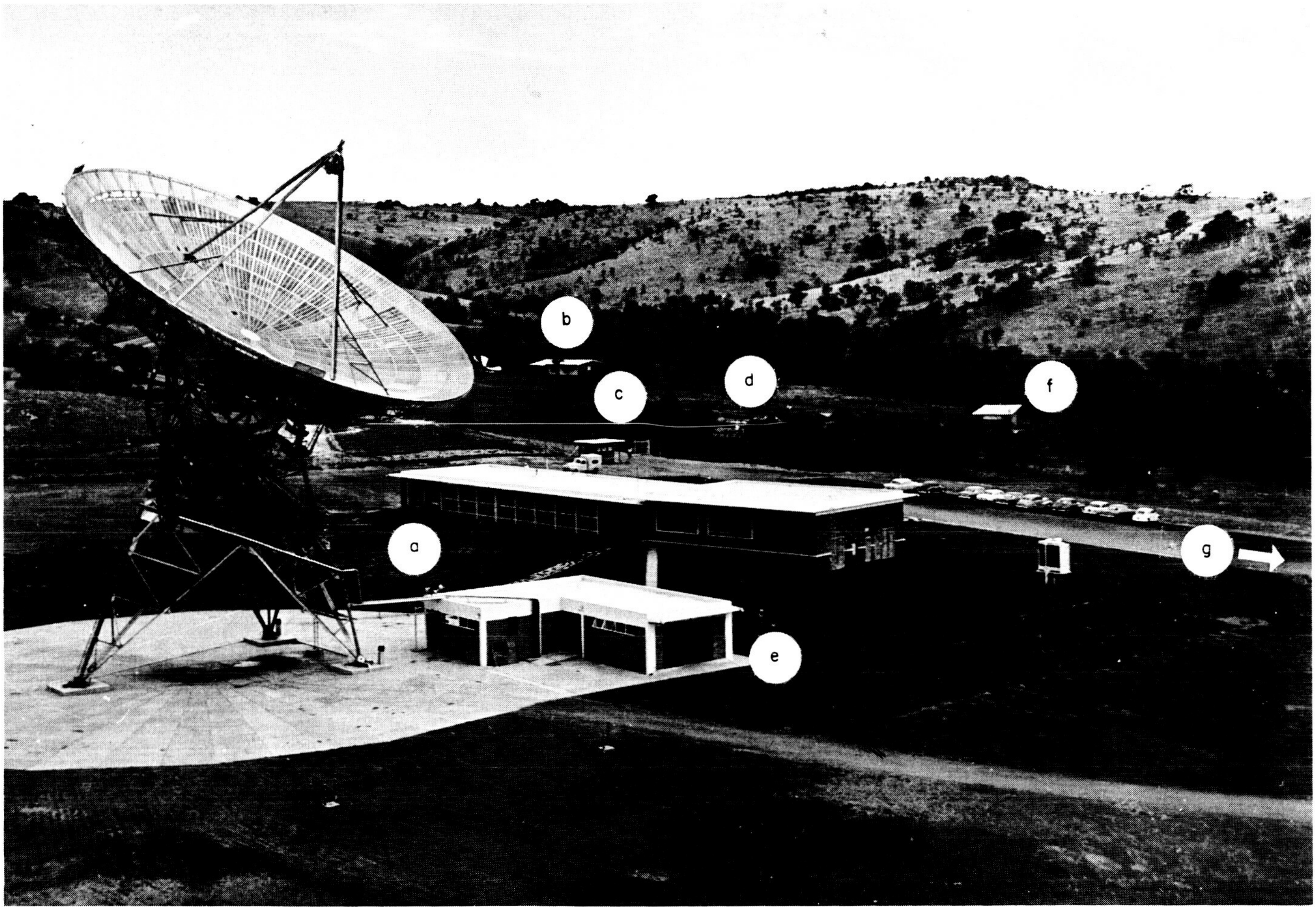
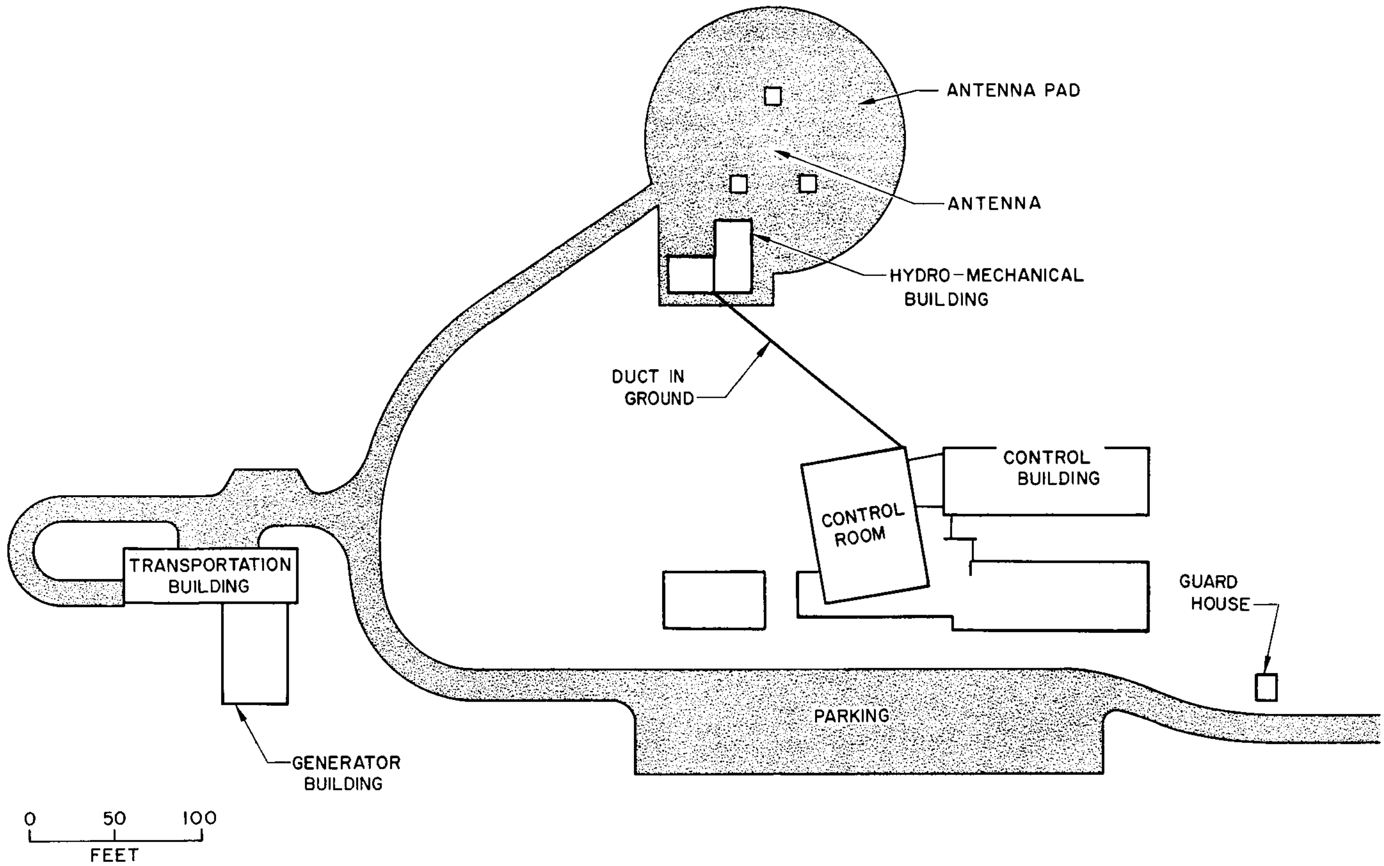


Fig. 11. Area map of Johannesburg Station

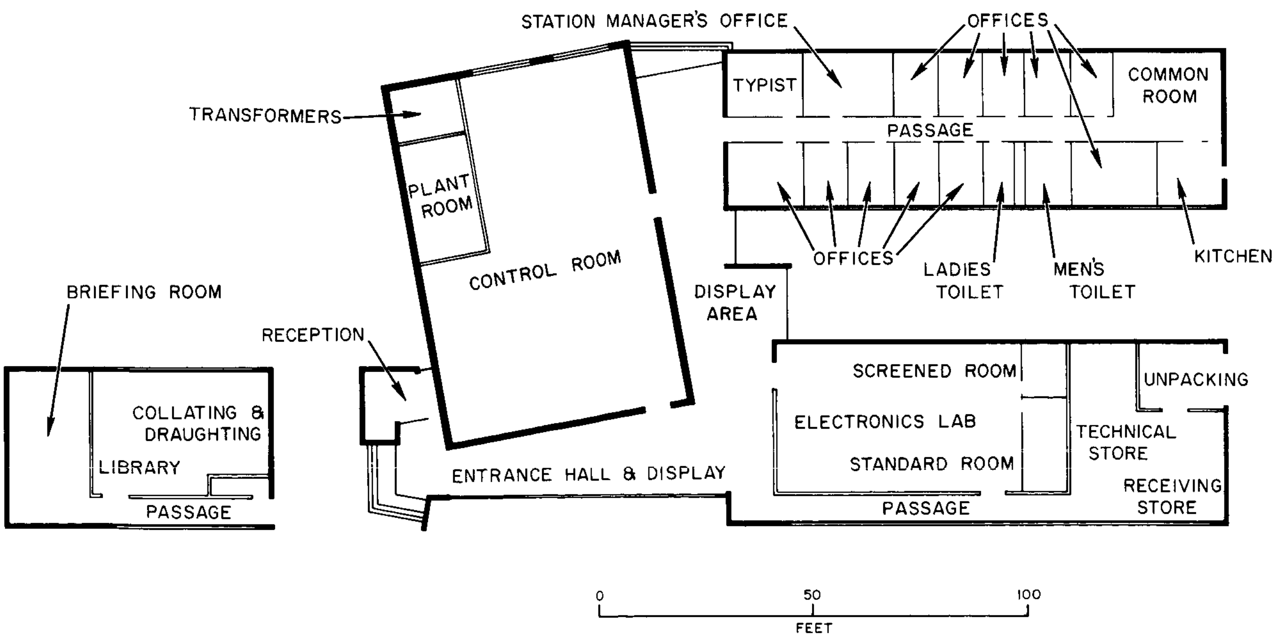


a. CONTROL BUILDING
b. STATION PERSONNEL HOUSING
c. GUARD HOUSE
d. MESS AND RECREATION BUILDING
e. HYDRO-MECHANICAL BUILDING
f. DORMITORY
g. TO TRANSPORT AND GENERATOR BUILDING

Fig. 12. Johannesburg Station

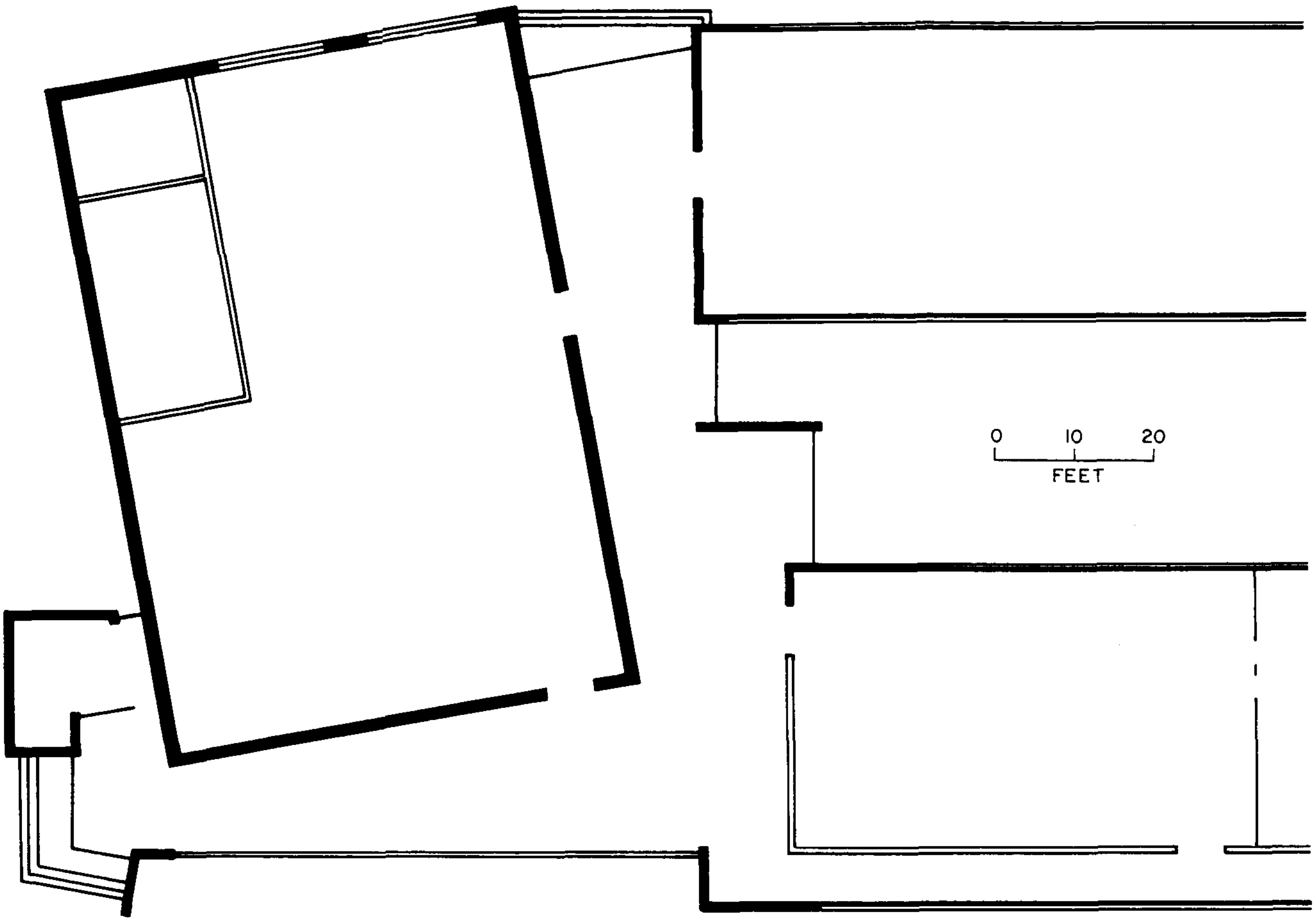


a. STATION MAP

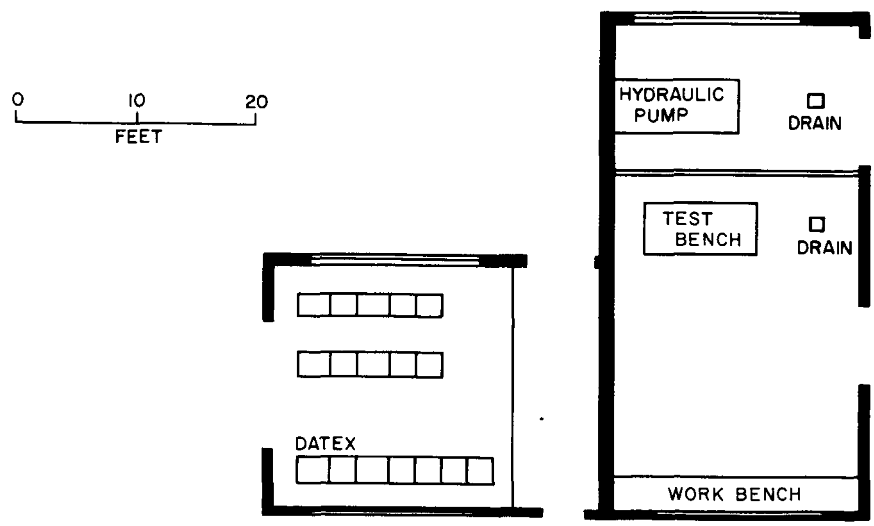


b. CONTROL BUILDING

Fig. 13. Johannesburg Station: station map and control building floor plan



a. CONTROL ROOM



b. HYDRO-MECHANICAL BUILDING

Fig. 14. Johannesburg Station: building floor plans and equipment layouts

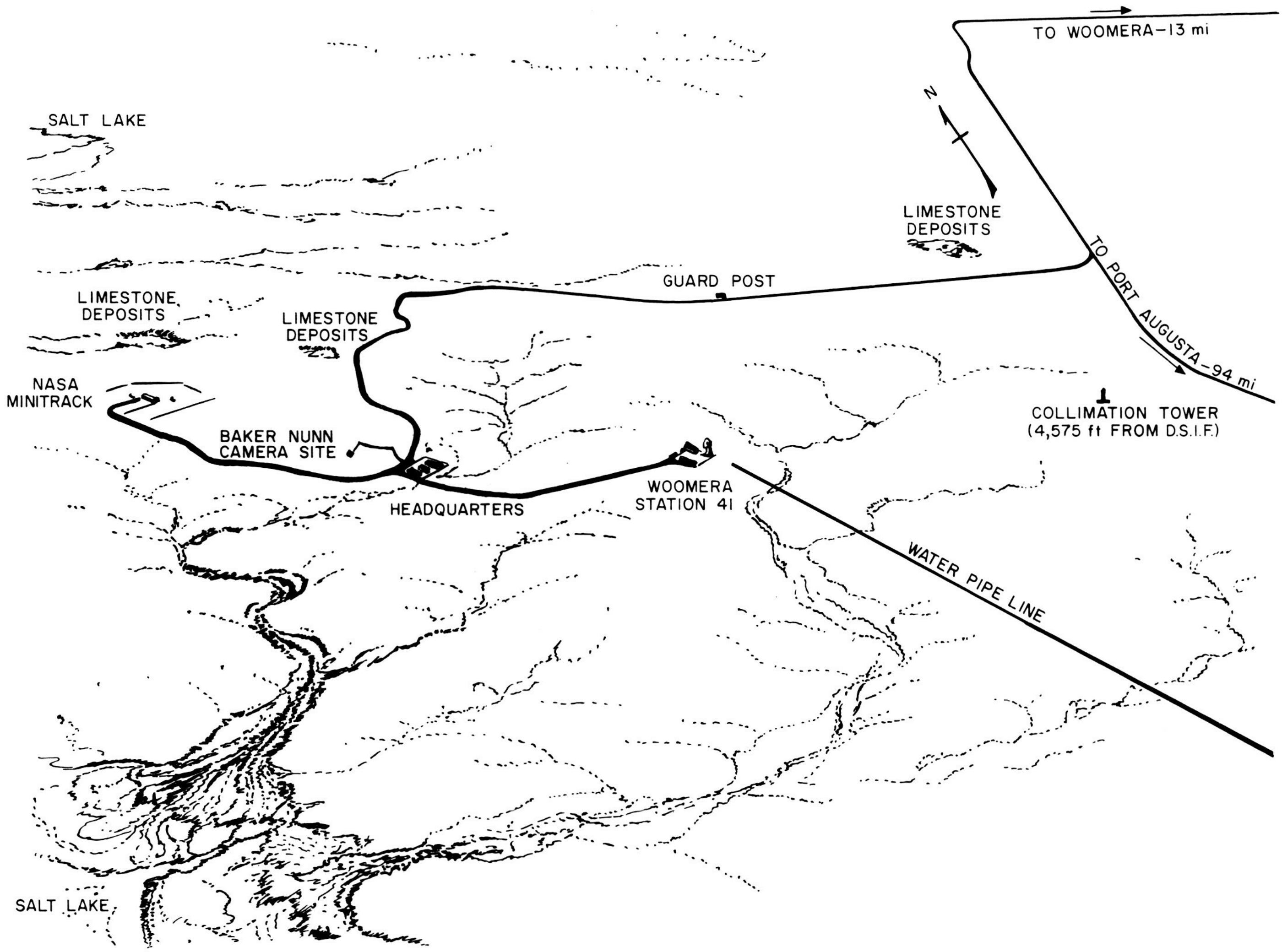
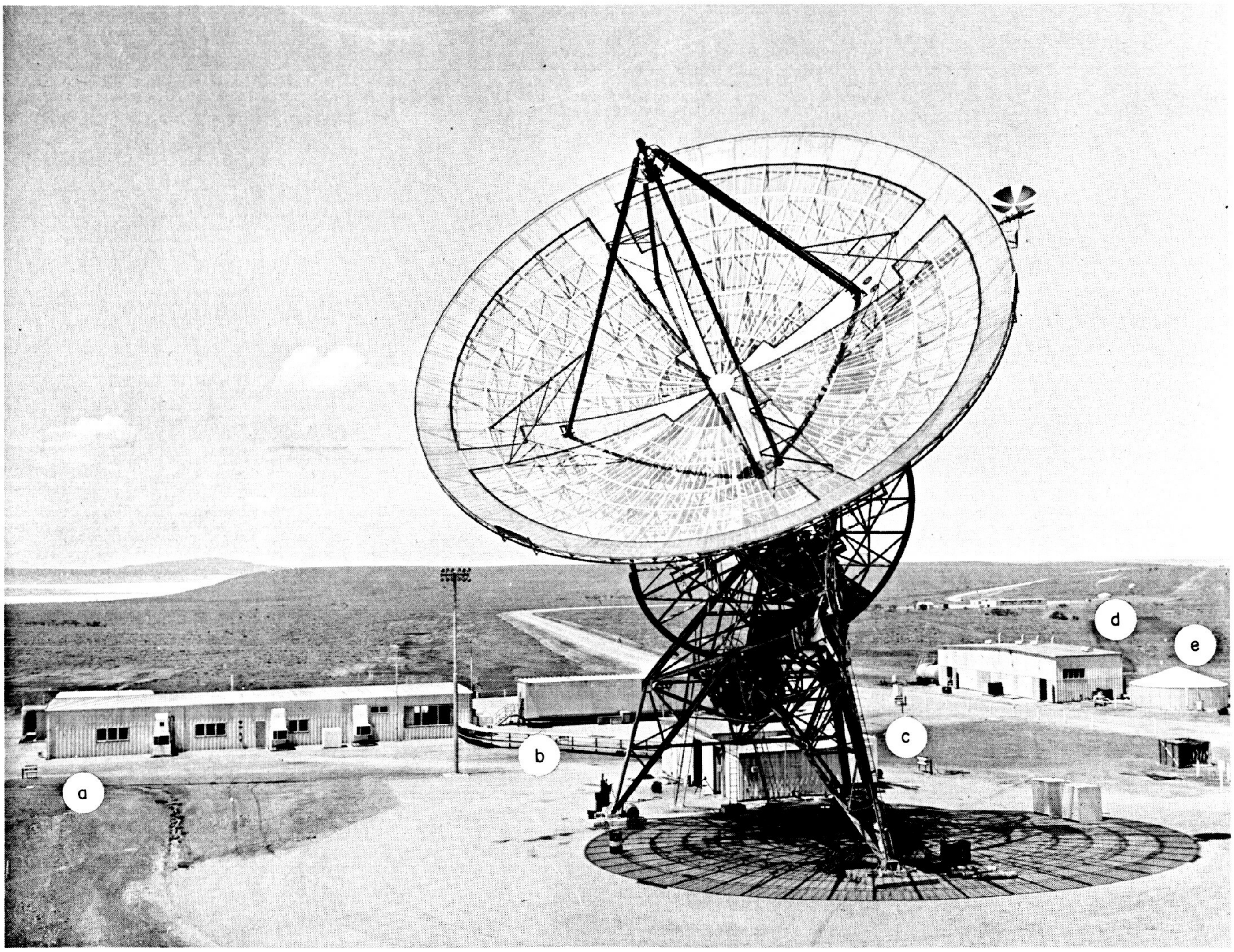


Fig. 15. Area map of Woomera Station



a. CONTROL BUILDING
b. TRAILER SHED
c. HYDRO-MECHANICAL BUILDING
d. GENERATOR BUILDING
e. WATER TANK

Fig. 16. Woomera Station

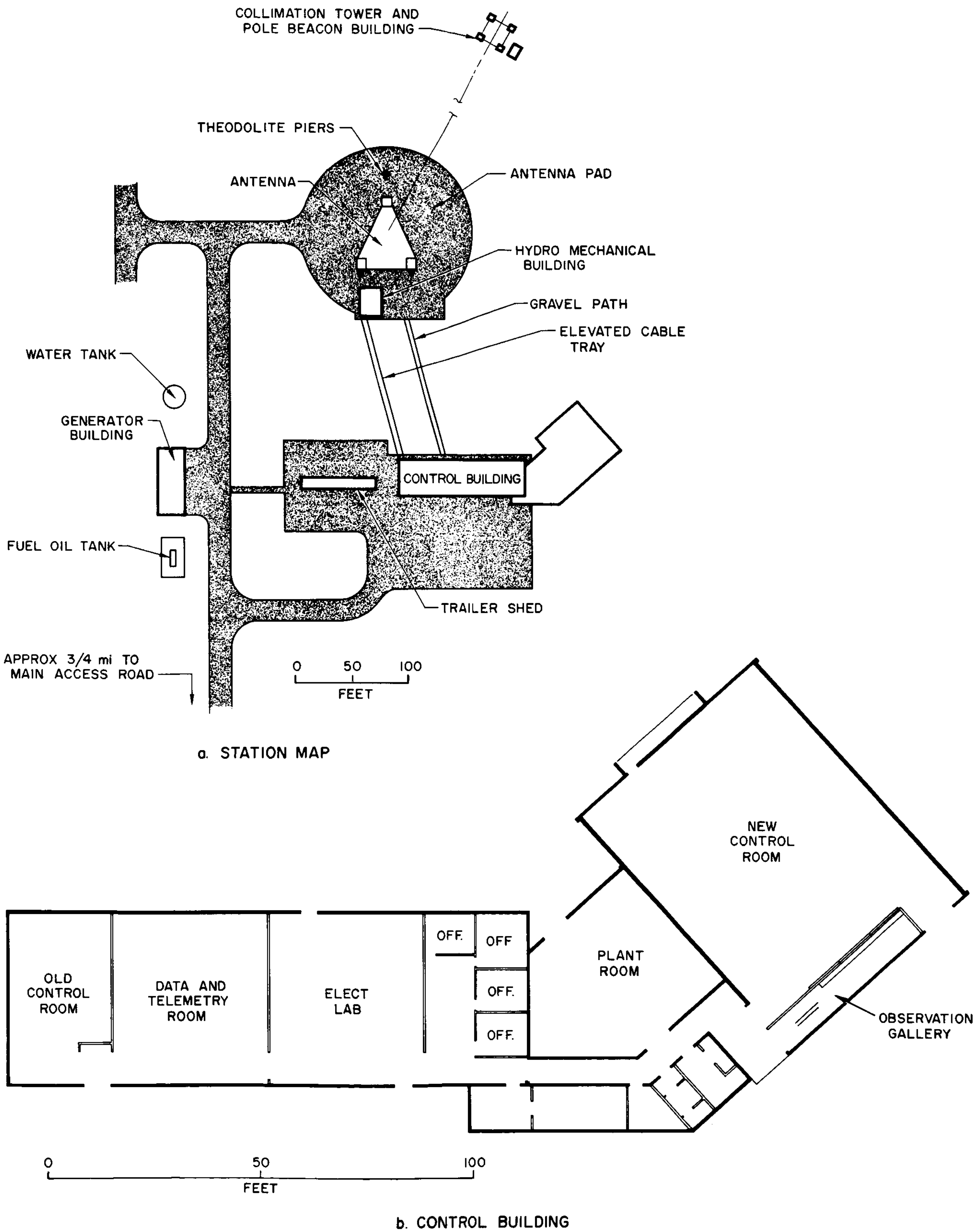
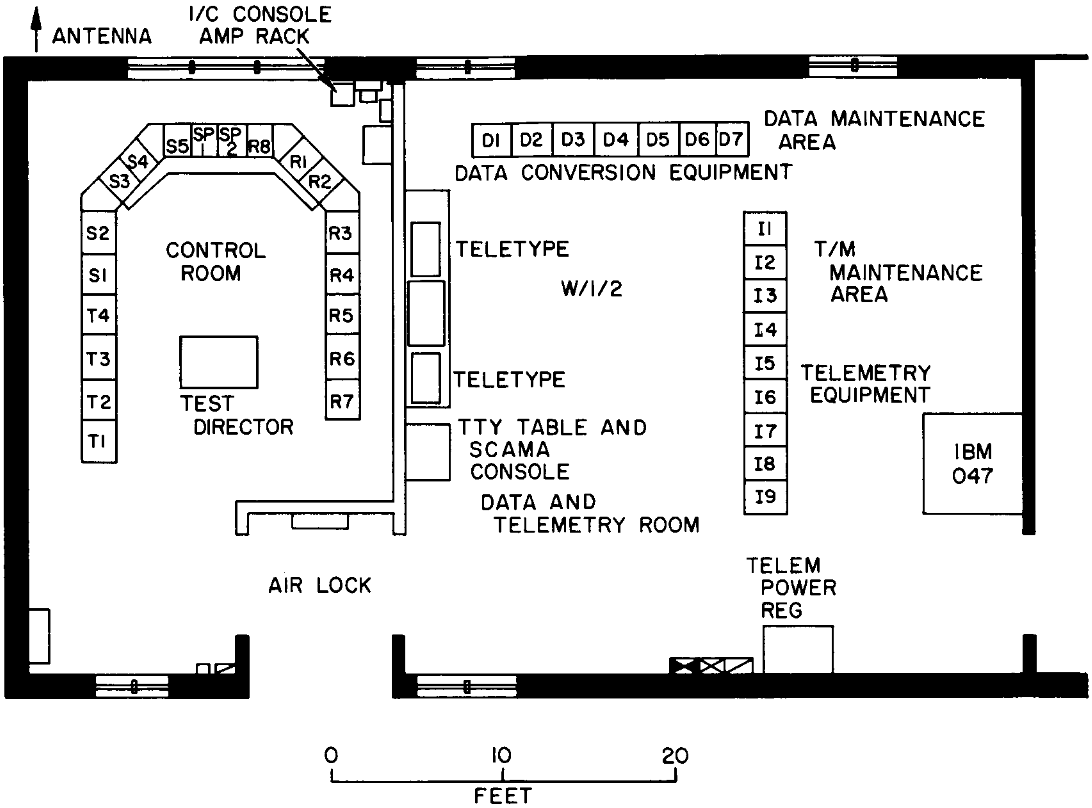
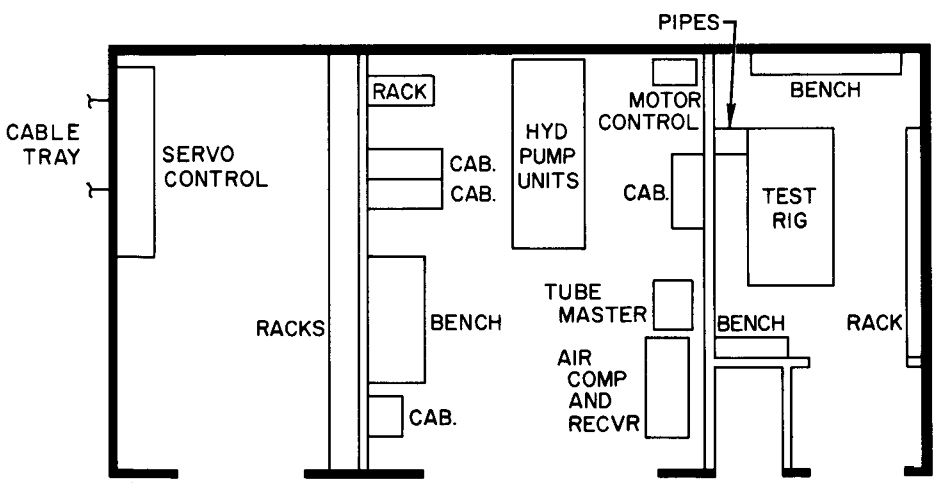


Fig. 17. Woomera Station: station map and control building floor plan



a. CONTROL AND INSTRUMENTATION ROOMS



b. HYDRO-MECHANICAL BUILDING

Fig. 18. Woomera Station: building floor plans and equipment layouts

a. RECEIVING AND TRANSMITTING ANTENNA

b. TRANSMITTER AND RECEIVER TRAILER

c. CHECKOUT ANTENNA (COLLIMATION)

d. TELEMETRY TRAILER

Fig. 19. Spacecraft Monitoring Station, Cape Kennedy

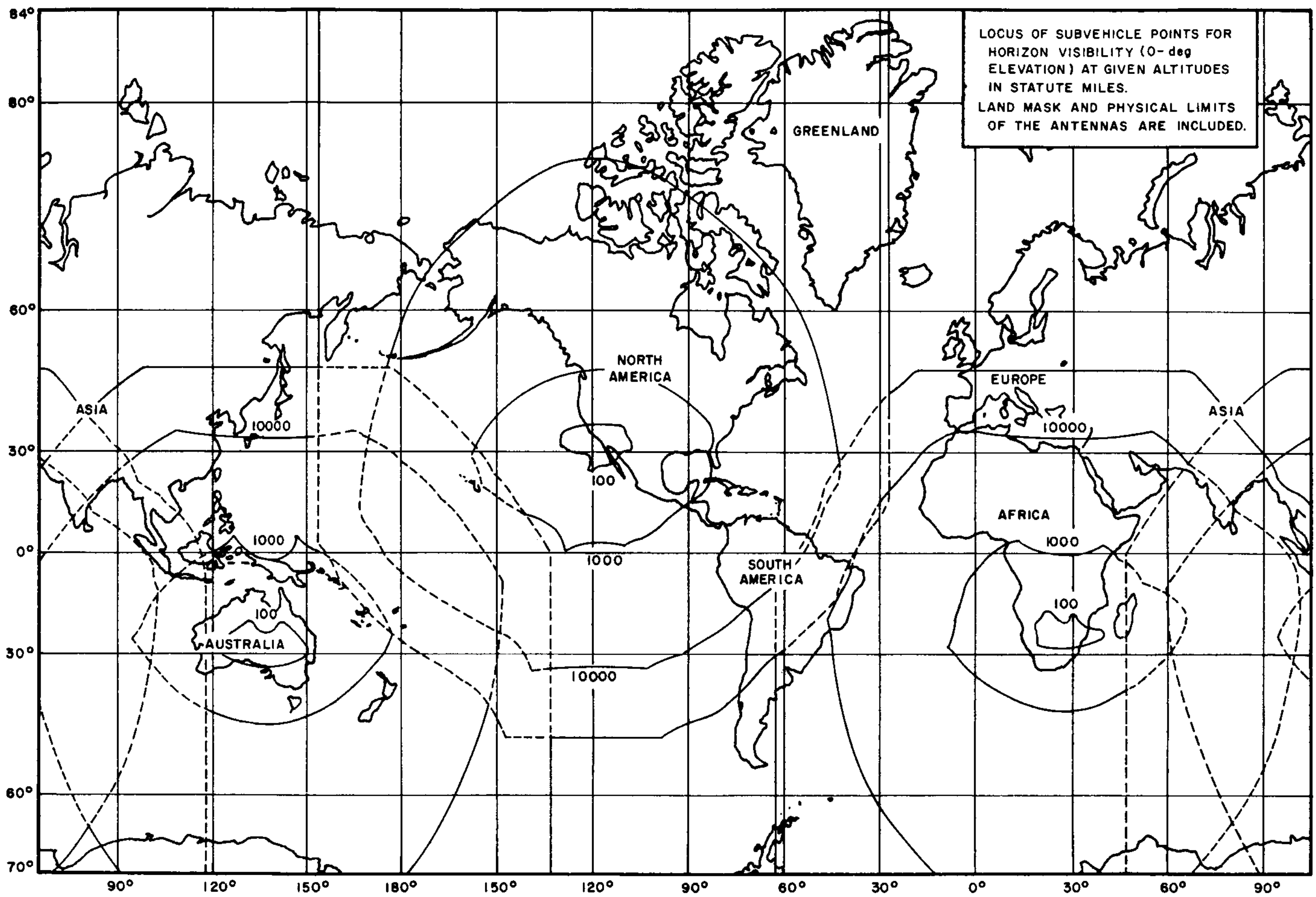


Fig. 20. Station coverage for 85-ft-diameter polar mount DSIF antenna (Goldstone, Woomera, Johannesburg)

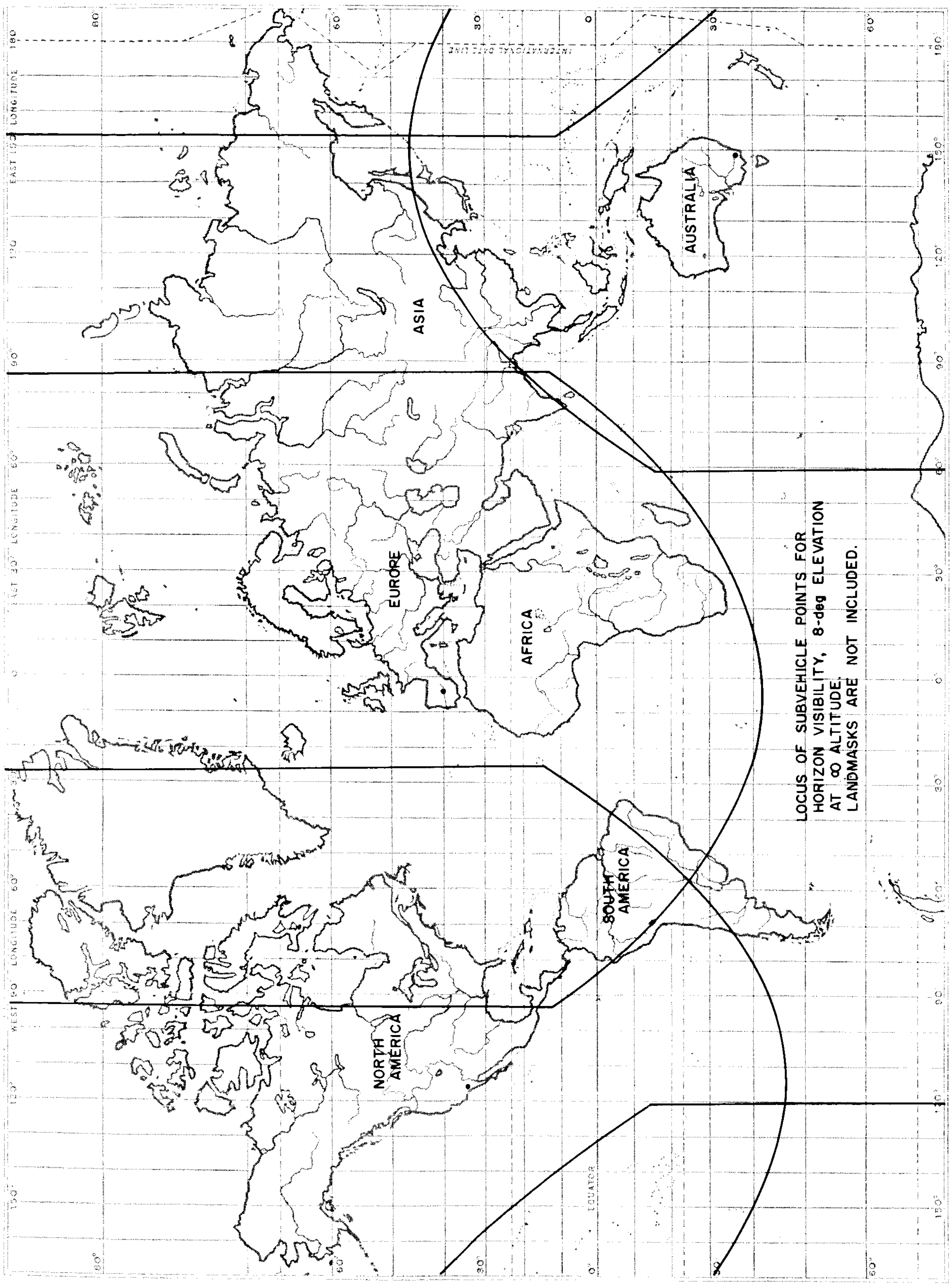


Fig. 21. Station coverage for 85-ft-diameter polar mount DSIF antenna (Goldstone, Madrid, Canberra)

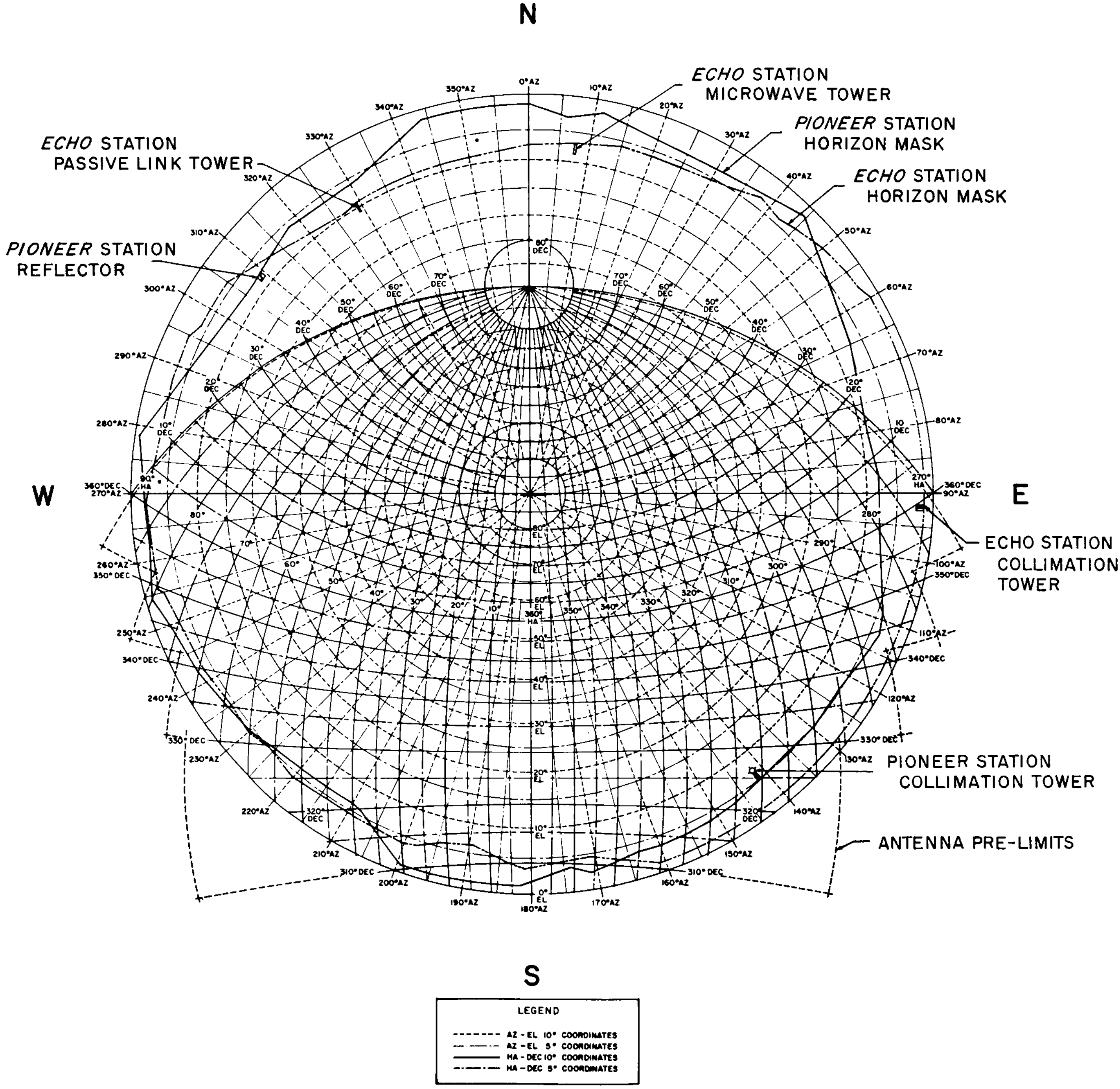


Fig. 22. Goldstone Az-El and HA-Dec coordinates: stereographic projection for 85-ft-diameter polar mount antennas

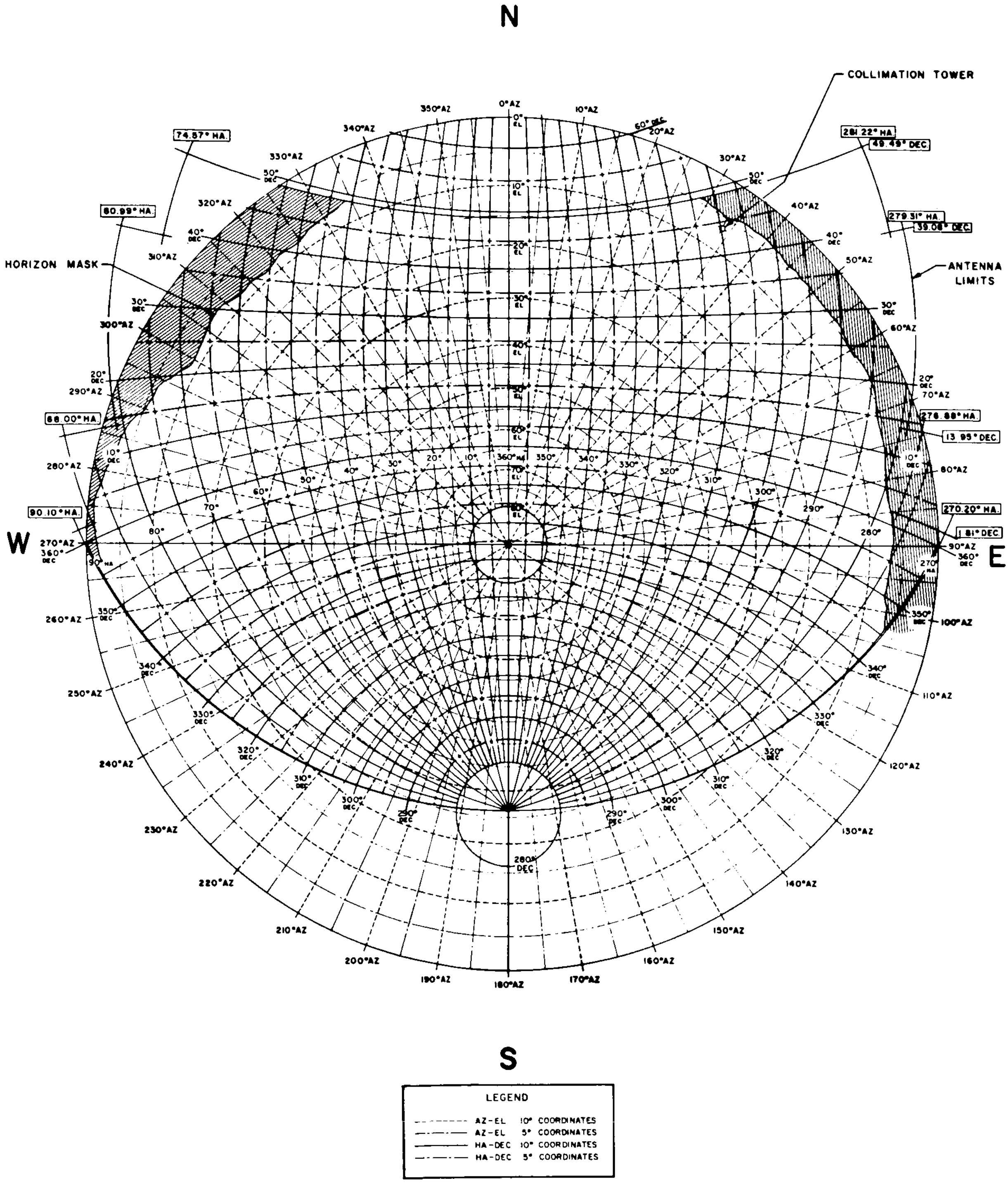


Fig. 23. Johannesburg Az-El and HA-Dec coordinates: stereographic projection for 85-ft-diameter polar mount antennas

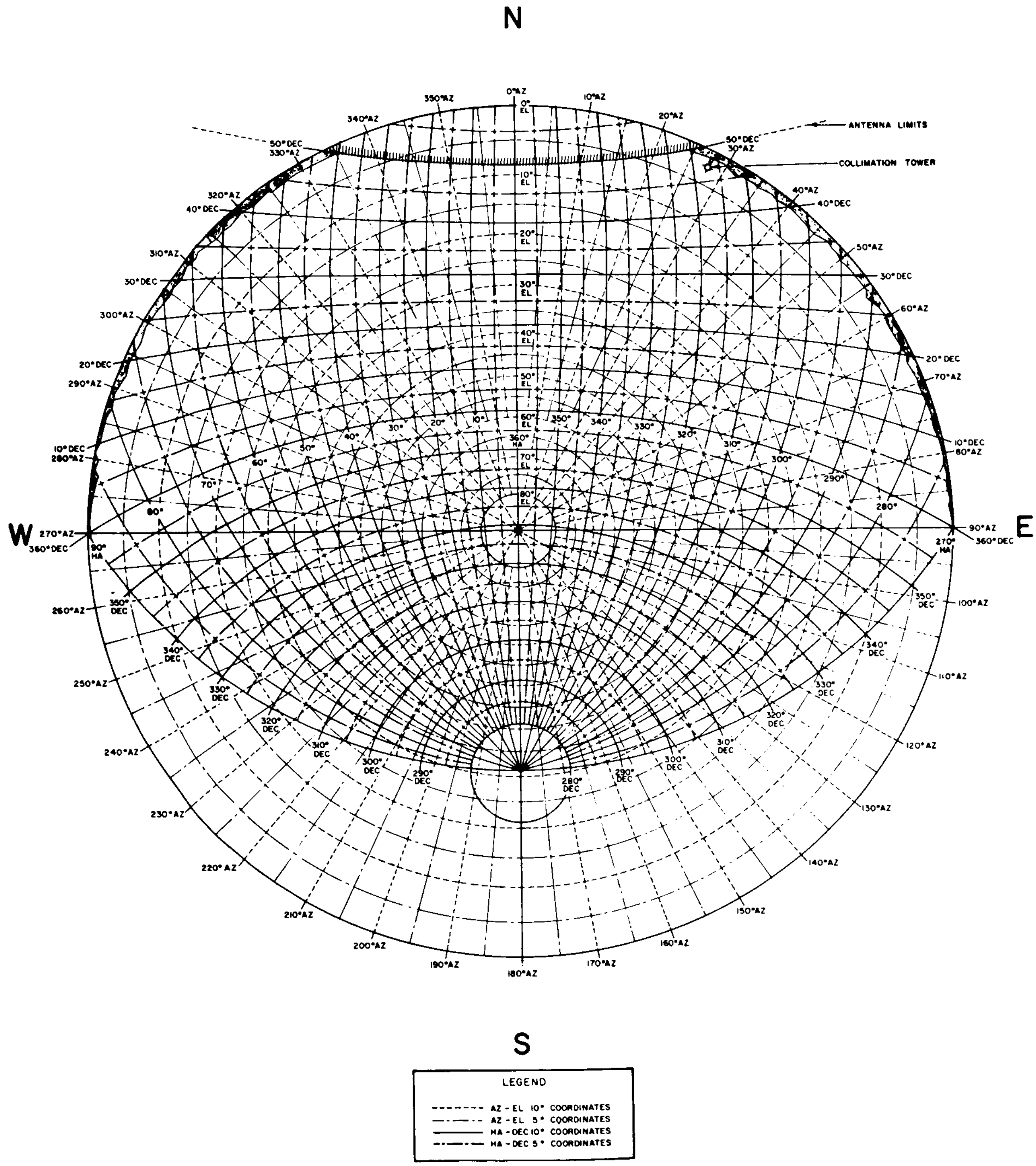


Fig. 24. Woomera Az-El and HA-Dec coordinates: stereographic projection for 85-ft-diameter polar mount antennas

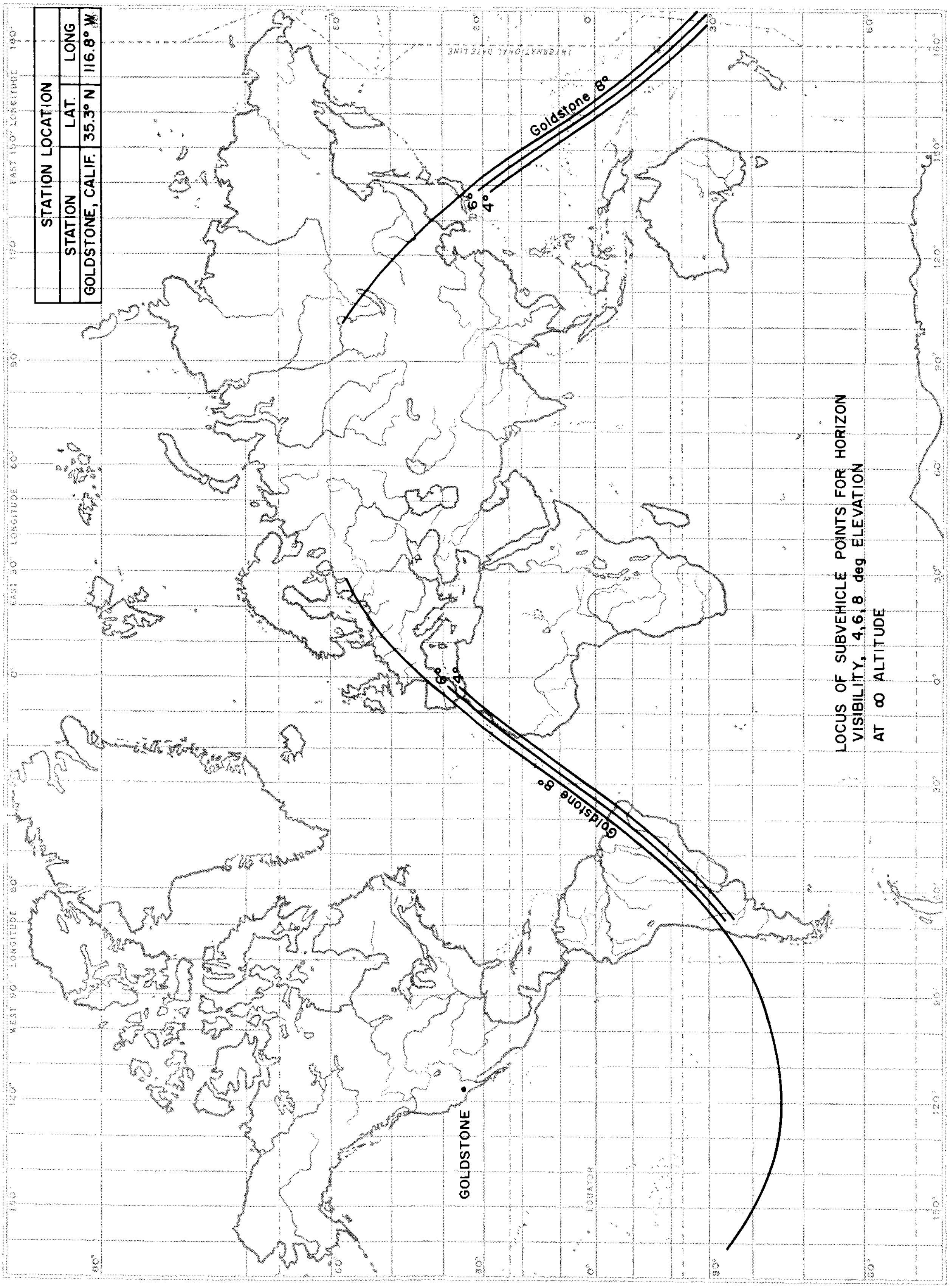


Fig. 25. Station coverage of 210-ft-diameter Az-El mount DSIF antenna under construction at Goldstone

III. DEEP SPACE INSTRUMENTATION FACILITY SYSTEM CAPABILITIES

At the present time the DSIF is equipped to communicate with spacecraft at L-band frequencies (nominal 890 Mc transmit and 960 Mc receive). This capability will be maintained through July 1965 for the *Ranger* project only, provided authorization to use these frequencies is extended. The DSIF will become operational at all stations on S-band frequencies during the period from July 1964 to July 1965 (see Table 2).

Table 2. S-band implementation schedule

Station	Date operationally capable	
	L-S[a]	Full S-band
Goldstone (Pioneer)		May 1964
Goldstone (Echo)		June 1965
Woomera	September 1964	July 1965
Johannesburg	September 1964	July 1965
Canberra		January 1965
Madrid		June 1965
Spacecraft monitoring		May 1965

[a]L-S is an interim capability obtained by providing sufficient equipment to receive S-band frequencies on the L-band receiver; IF frequencies and information bandwidths are the same as for the L-band receiver system.

Appendix A contains a description of a method of control of the telecommunication system parameters.

A. Tracking Capability

1. Angle Tracking

The automatic angle tracking systems used in the DSIF are of the simultaneous-lobing type. The 85-ft HA-Dec antennas (I)[2] have two maximum tracking rate capabilities, 0.7 deg/sec and 0.03 deg/sec about each axis, depending on tracking system bandwidth requirements. During the periods in which angle tracking accuracy is most significant (e.g., when data for an initial ephemeris calculation are required), the strong signal levels available result in a root-mean-square angle-tracking error from 0.01 to 0.02 deg. The rms tracking error at receiver threshold increases to approximately 0.05 deg. Bias errors lie in the range of -0.1 to $+0.1$ deg. However, optical calibration techniques such as star tracking have led to the accurate determination of certain bias errors, and these are removed from the observed data at the computational facility. Resolution of the angle encoders is 0.002 deg.

The 85-ft Az-El mount antenna which is located at the Goldstone (Venus) site is used primarily in engineering and development work for the DSIF. However, in emergencies, or where special equipment installed on this antenna is required, this station may be used in DSIF operations. An example of this is the planned use of the 100-kw transmitter, which is installed on the 85-ft antenna at the Venus site, in operations with the *Mariner* spacecraft which is scheduled to pass by the planet Mars in 1965. This antenna is capable of tracking rates up to 2.0 deg/sec and has rms tracking errors comparable to the polar-mount 85-ft antennas.

The expected performance of the 210-ft altazimuth-mount DSIF antennas (authorized for Goldstone; proposed for Madrid and Canberra) is shown in Table 3. Tracking errors and bias data will be determined upon completion of the antenna installation.

Angle data from all the DSIF antennas are digitally encoded by angle sensors on the antenna, and the coded signals are recorded in teletype code on punched paper tape by the data handling equipment.

2. Doppler

One- and two-way doppler measurement capability is included at all stations in the DSIF. Two-way doppler requires a ground transmitter in the vicinity of the DSIF receiver to achieve frequency control by a single exciter. The distance at which the DSIF stations can obtain doppler data is, of course, dependent on the sensitivity of the spacecraft receiver and the power output of the spacecraft transponder; if the carrier can be tracked in phase, doppler data can be made available.

One-way doppler accuracy is 30 m/sec, and two-way accuracy is 0.003 m/sec. The latter accuracy is based upon a minimum of 5 hr of tracking using correlation periods of 60 sec.

[2]Throughout this report the following code is employed: (I) designates existing and installed facilities; (A) designates authorized and funded projects; (P) designates proposed but not yet funded projects.

Table 3. 210-ft altazimuth antenna: expected performance

Azimuth coverage, deg	±300 (from SE at Goldstone)
Elevation coverage, deg	5 to 88 (tracking sidereal target) 4.5 to 90.5 (final limits)
Pointing accuracy, deg	0.02 pointing 0.01 tracking
Maximum angular rate azimuth, deg/sec	0.5 (wind ≤ 30 mph)
Maximum angular rate elevation, deg/sec	0.5 (wind ≤ 30 mph)
Maximum acceleration azimuth, deg/sec	0.2 (wind ≤ 30 mph)
Maximum acceleration elevation, deg/sec	0.2 (wind ≤ 30 mph)
Servo bandwidth adjustment, cps	0.01 to 0.2
Gain at 2300 Mc, db	61
Beamwidth at 2300 Mc, deg	≈ 0.1
System temperature,[a] °K	23–25
Antenna temperature, °K	≈ 10
Reflector diameter, ft	210
Reflector F/D ratio	0.4235

[a]Includes maser amplifier, receiver, transmission line, listening feed, and the antenna pointing at a quiet sky.

Table 4. Data system sampling rates and doppler counting intervals

Available sampling rates		Available doppler counting intervals
1 sec	1 min	1 sec
2	2	5
3	3	10
4	4	20
5	5	30
6	6	40
7	7	50
8	8	60
9	9	continuous
10	10	
20	20	
30	30	
40	40	
50	50	
60	60	
70	70	
80	80	
90	90	

The accuracy of one-way doppler data is limited primarily by the average frequency instability of the spacecraft oscillator. The detected doppler in either the one- or two-way system is equal to the doppler shift at the received RF frequency with the addition of a 1-Mc bias. The 1-Mc bias is derived from the station's ultrastable oscillator.

Doppler frequency data are obtained by use of digital frequency counters whose basic timing frequency is obtained from the station's ultrastable oscillator. The available counting intervals and sampling rates are shown in Table 4. Two counters are used in any one of three different modes as follows:

Mode 1. Either counter (or both in parallel) counts the doppler frequency for a specific counting interval (always less than the sampling rate); the count is read out and then reset to zero and the process repeated.

Mode 2. Same as Mode 1 except the counters count alternately. In this case, the counting interval can be equal to or less than the sample rate. When the sample rate and counting interval are equal, the sum of the readings of both counters is equivalent to a continuous count.

Mode 3. One counter counts continuously while the other counter acts as a storage register to hold the sampled reading while the reading is read out. The reading rate is controlled by the sample rate, and the register counter is reset to zero after readout.

The first two modes are "destruct" modes, while the third mode is a "continuous" mode and provides a direct measurement of the change in range over the time interval.

3. Precision Ranging

A ranging system is presently under development by JPL and is planned for installation at the different stations when the S-band equipment is installed (see

Table 2). The system measures the time difference between two identical, separately generated, pseudorandom noise codes (one generated at the transmitter for modulation, and the other generated at the receiver for correlation detection) to represent range. The transponder in the spacecraft receives the code-modulated transmitted signal and retransmits the same modulation back to the ground. The transponder is called a "turnaround" transponder, and normal signal-to-noise ratios available with this type of system limit the measurement of range to less than 800,000 km. The resolution of the ranging system is 0.007 μsec round-trip time, which is approximately equivalent to 1.05 meters one way. However, worst-case estimates of the unknown time delays in the receiving system are expected to limit the accuracy of the ranging system to ± 0.1 μsec round-trip time, which is approximately equivalent to ± 15 meters one way.

The ranging system is operable as long as carrier phase coherence is maintained in the two-way system. The general mode of operation will be to initiate range modulation, establish range lock, and then remove range modulation and count carrier doppler cycles to maintain a range tally.

It is possible to extend this method of ranging to planetary distances by equipping the spacecraft transponder with the same type of pseudorandom code generator, which reconstructs the code before retransmission to the Earth. Such a system has been designed and built, and will be installed at Goldstone whenever there is a project requirement. It is not considered necessary at this time to equip each longitude with this capability.

4. Tracking-Data Handling

Tracking-data handling equipment is operational at all Deep Space Stations. This equipment automatically punches out, on paper tape and in standard Baudot teleprinter five-hole code, characters which represent carriage return, line feed, figures, spaces, and the following technical information:

Station identification number

Spacecraft identification number

Data condition

Greenwich Mean Time (GMT)

Antenna hour or azimuth angle

Antenna declination or elevation angle

Doppler frequency

Range data including "range condition" code (A)

Transmitter frequency (A)

Day of year

The format is so designed that one complete set of information is printed on one or two lines of a teleprinter page printer, which will accept a nominal 60 characters per line, including spaces (see Table 5).

A complete line (or two lines) of information is called a data sample and the rate at which these samples are read out is determined by the settings of the sampling rate switches (see Table 4). The system is capable of punching at a rate of 60 characters per sec, using two punches connected to operate singly or in parallel. A control is available so that both punches can operate in parallel but with one punch set to punch at 1/1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9 or 1/10 the rate of the other punch. Since the normal maximum teletype speed is 6 characters per sec (60 words per min), it is possible to use one punch to punch out data for real-time teleprinter transmission while the other punch is punching out data at the maximum rate. The rate of tracking-data sampling is generally determined by project requirements and varies considerably over the period of a mission.

B. *Communications*

1. Allocated DSIF Frequencies

In the past, JPL projects have used L-band frequencies, i.e., 890 Mc from Earth to spacecraft and 960 Mc from spacecraft to Earth. The exact ratio, for coherent doppler, is 89/96. These frequencies are presently being used on the *Ranger* spacecraft and will be used until the middle of 1965. Beginning in 1964, all other JPL projects and non-JPL projects, except *Apollo*, which will use the DSIF for tracking and data acquisition, will use S-band frequencies, i.e., 2110–2120 Mc from Earth to spacecraft and 2290–2300 Mc from spacecraft to Earth with frequencies being in the exact ratio of 221/240. This frequency band has been arbitrarily divided into transmitting and receiving channels in accordance with Table 6. The channels operate in pairs to maintain the 221/240 ratio, thus permitting individual communications to and from different spacecraft which may be operational within the same time period. Since the frequency allocations are not consistent with the ratio of 221/240, all of the allocated spectrum is not usable for two-way communication.

Table 5. Teletype format[a]

Station identification number	Spacecraft identification number	Data condition (doppler count; receiver and servo; doppler mode; frequency standard)	GMT (hr, min, sec)	Hour angle (deg, thousandths of a deg)	Declination (deg, thousandths of a deg)	Doppler cycle count, cps	Day of year
12	53	2000	014500	359770	345558	1011321422	301
12	53	2000	014502	359477	345861	1011328362	301
12	53	2000	014504	359185	346163	1011335246	301
12	53	2000	014506	358893	346646	1011342128	301
12	53	2000	014508	358601	346768	1011349004	301
12	53	2000	014510	359308	347071	1011355882	301
12	53	2000	014512	358016	347373	1011362761	301
12	53	2000	014514	357725	347675	1011369630	301
12	53	2000	014516	357433	347978	1011376503	301
12	53	2000	014518	357141	348280	1011383378	301
12	53	2000	014520	356849	348582	1011390250	301
12	53	2000	014522	356557	348884	1011397122	301

[a]The format is controlled by a programmable patchboard, and the total number of characters can be changed as required. The data can be listed in either one or two lines. The sample shows only one line and is not necessarily the format which will be used. A total of 11 digits will be used to show ranging data, including range condition code, and from 3 to 7 digits will be used to show transmitter frequency.

Table 6. DSIF space mission frequencies

Channel	Ground receiver frequency, Channel A	Ground transmitter frequency, Channel B
1	2290.185185	—
2[a]	0.555556	—
3	0.925926	—
4	1.296296	—
5[a,b]	1.666667	2110.243056
6	2.037037	0.584105
7	2.407407	0.925154
8[a]	2.777778	1.266204
9	3.148148	1.607253
10	3.518519	1.948303
11*	3.888889	2.289352
12	4.259259	2.630401
13	4.629630	2.971451
14[a,b]	5.000000	3.312500
15	5.370370	3.653549
16	5.740741	3.994599
17[a]	6.111111	4.335648
18	6.481481	4.676697
19	6.851852	5.017747
20[a]	7.222222	5.358796
21	7.592593	5.699846
22	7.962963	6.040895
23[a,b]	8.333333	6.381944
24	8.703704	6.722994
25	9.074074	7.064043
26[a]	9.444444	7.405092
27	9.814815	7.746142
28	—	8.087191
29	—	8.428241
30	—	8.769290
31	—	9.110339
32	—	9.451389
33	—	9.792438

[a]Recommended center frequencies for channels requiring 1-Mc bandwidths.

[b]Recommended center frequencies for channels requiring 3-1/3-Mc bandwidths.

Three of the DSIF stations, namely Goldstone (Echo), Johannesburg, and Woomera will maintain their L-band capability until it is no longer required by the *Ranger* Project. The three new stations—Canberra, Madrid, and Goldstone (Mars)—will be installed with S-band equipment only.

The Goldstone (Echo), Johannesburg, and Woomera stations use L-band feeds and receiving equipment mounted at the focal point of the parabolic reflector. The S-band feeds and a portion of the receiving equipment will be mounted in a cassegrain cone which will always remain on the antenna, and to convert from S- to L-band it will be necessary to remove the hyperbolic secondary reflector and reinstall the L-band feed. This conversion process requires about 24 hr as does the reverse procedure.

2. Telemetry Assembly of Receiver Subsystem

The S-band phase-lock-loop receiver is a double conversion superheterodyne with a 50-Mc first IF and a 10-Mc second IF. The output of the 10-Mc IF passes through a bandpass filter which can be selected to have any one of four different bandwidths: 3.3 Mc, 420 kc, 20 kc, and 4.5 kc. When required, this filter may be replaced with one designed to meet particular characteristics. The bandpass filter has two outputs. One output feeds an IF amplifier with a 3.3-Mc bandwidth input to the filter which furnishes signal voltages to the input of the down converter associated with the FR-700 video tape recorder. The other output feeds a wideband phase detector which in turn has two outputs. One of these outputs is a video amplifier with a bandwidth of 300 cps to 1.65 Mc; the other is a dc amplifier with a bandwidth of dc to 250 kc. The latter is called the narrow-band telemetry output and would be the output used to provide inputs to the various discriminators when standard IRIG telemetry channels are used. Some stations are equipped with standard phase-lock IRIG discriminators and channel selectors for channels 1 through 8. If necessary, arrangements can be made to furnish an output from the 50-Mc IF amplifier with a bandwidth of 10 Mc.

3. Telemetry Data Handling

Processing of telemetry data for real-time display and recording at the station, as well as transmission to a central control facility, is accomplished by special-purpose equipment which will demodulate, decommutate, edit, and format the data. Owing to the wide variety of telemetry transmission techniques in use, this equipment has been special purpose for a particular mission and is normally supplied by the spacecraft project. Where telemetry formats of two or more missions are similar, common equipment for these missions can be used subject to prior agreement between the spacecraft project offices.

The following equipment is generally required.

1. Demodulator for detecting the telemetered data from the telemetry subcarrier(s) in real time.
2. Decommutator for sorting the incoming telemetry data stream into discrete data words, identifying the measurement (commutator address and/or word address), and providing an output to local display devices and/or data transmission equipment for transmission to a central control point.
3. Data transmission equipment to edit, format, encode, and time label the telemetry data so that it may be transmitted to the central control point by teletype lines or high-speed data lines. This equipment functions as the interface device between the incoming telemetry data stream and the outgoing communication circuits.

For all data transmitted to the central control point by communications circuits it is necessary to add information to the data stream to identify spacecraft, tracking station, time of day when the data were received at the station (GMT), data type (e.g., telemetry data), and data format being used if this is a variable.

For teletype transmission, the station identification, spacecraft identification, and data type are inserted separately and automatically on the teletype line by a message preamble generator. This operation can be done because the data input to the teletype line is generally on punched paper tape. Therefore, the tape transmission can be stopped for insertion of the preamble. All other identification data (primarily, time and format type) must be inserted in the data format.

For the high-speed lines, all of the information required for identification of the data must be inserted in the data format.

In order to reduce the amount of special-purpose equipment which would be installed at the Deep Space Stations, it is planned to add, on an interim basis, certain additional items of equipment to the Digital Instrumentation System so that the SDS-910 computer used in this system can perform many of the functions previously handled by the special-purpose equipment. The types of functions which can be performed are:

1. Selective editing of spacecraft telemetry data.
2. Decommutation.
3. Generation of alarms.
4. Telemetry monitoring.
5. Processing of selected station instrumentation data.
6. Formatting telemetry data messages.
7. Verification of spacecraft command data both as received and as transmitted.
8. Generation and verification of command tapes.
9. Permissive and limit checking of commands.

The equipment to be added to the Digital Instrumentation System includes parallel input/output memory interface, arming for priority interrupts, a second input/output buffer, a communication buffer, a patch panel, a line printer (Goldstone only), and an increase in memory capacity to a total of 8192 words. This equipment will be added to the Goldstone (Pioneer), Johannesburg, Canberra, Madrid, and Cape Kennedy Monitoring stations at the time they are ready for S-band operation and will be available until July 1966. During this time the Digital Instrumentation System will be operating with the remaining SDS-920 computer in a reduced-capacity mode. After July 1966, the Digital Instrumentation System will be restored to its full capacity and a final design of an on-site data processing system will be installed at all Deep Space Stations. This system will have a capacity equal to or greater than the SDS-910 system described above.

Telemetry demodulators and input buffers will remain as special-purpose devices because of the varieties of spacecraft telemetry transmission schemes in use.

All telemetry data are normally recorded on magnetic tapes, before and after demodulation, as a permanent record of the telemetered data. These tapes are airmailed to JPL for nonreal-time processing as required.

4. Television

The capability of recording television pictures is provided in the receiver at two points. For very wideband signals an output 10 Mc wide is available from the 50-Mc first IF. A detection bandwidth of 300 cps to 1.65 Mc is also available from the output of the video amplifier which follows the wideband phase detector. Standard recording capability includes two FR-1400 and one FR-700 (not all-stations) magnetic-tape recorders. (See Table 7 for a listing of available recording capability; see Appendix B for a listing of the detailed capability of each recorder.) The FR-1400 is capable of recording a bandwidth of 400 cps to 1.5 Mc; the FR-700 is capable

Table 7. Existing and programmed recording equipment (See Appendix B for listing of recorder capabilities)

	Station: number and name								
		Goldstone							
	71 Spacecraft Monitor	11 Pioneer	12 Echo	14 Mars	51 Johannesburg	41 Woomera	42 Canberra	61 Madrid	59 Mobile
Oscillograph									
Sanborn Model 358	1(A)1965	1(I)	1(I)	1(A)1966	1(I)	1(I)	1(A)1965	1(A)1965	2(I)[a]
36 Channel CEC 5-123	1(I)	1(I)	1(I)	1(A)1966	1(I)	1(I)	1(A)1965	1(A)1965	1(I)[b]
Tape recorders									
CEC-752A					2(I)[c]	2(I)[c]			
Ampex FR-107C/1200	(A)1964	1(A)1964	2(I)[d]	1(A)1966	1(A)1964	1(A)1964	1(A)1965	1(A)1965	2(I)
Ampex FR-1400	2(A)1965	2(I)1964	2(A)1964	2(A)1966	2(A)1964	2(A)1964	2(A)1965	2(A)1965	
Ampex FR-700		1(A)1964			1(A)1964		1(A)1964		
Ampex FR-600	2(I)[e]								

A: authorized. I: installed.
[a]Models 158 rather than 358.
[b]Midwest Model 603.
[c]Will be removed when the FR-107 and FR-1400's are installed.
[d]One will be removed when the FR-1400's are installed.
[e]Will be updated to FR-1400.

of recording a bandwidth of 10 cps to 4 Mc. The former uses longitudinal recording at speeds up to 120 in./sec and is normally used as a postdetection recorder. The FR-700 is a special-purpose recorder using a transverse rotating head and is intended for extremely wideband signals such as video. It can be used for predetection recording of the 10-Mc second IF, by down conversion to a lower frequency, whenever the demodulation method is unknown or when demodulation on site will destroy some of the received data.

5. Ground Command and Control

All presently planned JPL projects use a digital command and control system with a transmission rate of one bit per sec. A ground command subsystem which is designed to meet the requirements of the *Ranger* and *Mariner* communication systems and is adaptable to other systems of a similar design is installed at all the stations and is authorized for Madrid and Canberra.

Three successive identical commands (each being 18 bits long for *Ranger* and 26 bits long for *Mariner*) are sent by teleprinter circuits to the station and received on punched paper tape. This tape is placed in the tape reader of the ground command subsystem; then it is read into the system where the command is verified, displayed, and recorded on punched paper tape. Initiation of actual command-modulated RF transmission can be done manually or automatically by insertion of a given time of day. During transmission to the spacecraft the RF signal is detected and compared bit by bit with the stored command. Transmission is inhibited when an error is detected by this monitor. Actual transmissions are recorded on punched paper tape for future reference.

A nearly universal ground command and control system using a general-purpose digital computer is under design, with installation in the DSIF planned for 1966–68.

In the event that the communications design of a particular spacecraft is incompatible with the existing ground command subsystem, it will be necessary for the project to furnish sufficient mission-peculiar equipment to replace the functions of the present system. This equipment should (1) accept commands from punched paper tape received on teleprinter circuits, (2) be self checking, and (3) deliver a voltage from 0 to 2.5 volts peak into 20 ohms.

6. Recording Equipment

The recording equipment installed or programmed for installation at each DSIF site is designed to allow recording of a variety of signals from spacecraft and station sources. The types of available equipment are shown in Table 7, and a listing of their capability is given in Appendix B. Signal-conditioning equipment of various types is also provided.

The standard magnetic-tape recording capability of a station will consist of two Ampex FR-1400 recorders, and they normally will be used to record the detected telemetry output from the phase-lock receivers. An FR-107C/1200 recorder, which will be available at each station, will be used for utility purposes. When necessary, recorders capable of recording wider bandwidths will be installed. An example is the installation of FR-700 recorders in 1964 at Goldstone (Pioneer), Johannesburg, and Canberra for the recording of video data from the *Surveyor* spacecraft. Such recorders can be used for the recording of predetection signals whenever this is considered to be necessary. The FR-1400 recorders have direct, FM, and digital record and reproduce capability at six standard speeds varying from 3-¾ to 120 in./sec, and the FR-107C/1200 recorders have direct record and reproduce capability only at six standard speeds varying from 1-⅞ to 60 in./sec. Both types use ½-in. tape. The FR-700 operates at either 12-½ or 25 in./sec and uses 2-in. wide tape.

Oscillograph recorders are used primarily for real-time system evaluation. In most cases, oscillographic recordings duplicate magnetic tape recordings of the ground system parameters.

7. Frequency and Time Standards

The basic frequency standards at the stations consist of two stable crystal oscillators (one for redundancy). In 1964 these oscillators will be supplemented with two atomic standard (rubidium vapor) oscillators per station. Using the crystal oscillators for the timing standard, the drift is stable to 2 parts in 10^{10} over 24 hr, and the initial frequency setting error is less than 5 parts in 10^9. Local time readout can be synchronized to WWV or WWVH to at least 10 millisec. Using the atomic standard oscillators, the drift error is not greater than 2 parts in 10^{11}. Using VLF receivers and WWVL it is anticipated that local time settings can be made to 3 millisec or less.

8. Special-Purpose Equipment

The major part of the DSIF equipment is or will be standardized for the purpose of reducing the cost of spares, ensuring equalized high performance, and allowing standard training, maintenance, checkout, and countdown procedure to be utilized. Such standardized equipment, qualified for use in the DSIF, is designated as Goldstone Duplicate Standard (GSDS).

In general, special-purpose communications equipment is limited to modulation, demodulation, voice communications, and data handling equipment specifically required to satisfy a particular project need. Responsibility for funding and engineering of this special-purpose equipment belongs to the program using the equipment. However, spares requirements, interface configurations, operational procedures, etc., must be coordinated through the DSIF. Facility negotiations and schedules are the responsibility of the DSIF. Operation of specialized equipment is decided by agreement between cognizant program and DSIF personnel.

9. Interstation Communications

A NASA-operated full duplex teleprinter (TTY-FD) communications net presently exists which links the Goldstone, Woomera, and Johannesburg Deep Space Stations to the JPL Space Flight Operations Facility. Commercial voice circuits between the Deep Space Stations and the SFOF are also available. The primary function of TTY-FD and voice circuits is to transmit tracking and telemetry data (see Table 5) and to permit operational control of the DSIF net. The existing and future intersite communications circuits are shown in Fig. 26.

A microwave link between Goldstone and the SFOF at JPL was made operational early in 1964. The link is capable of transmitting real-time telemetry, tracking, and video data from Goldstone to JPL. It has the following capabilities:

1. One 6-Mc video channel, Goldstone to JPL only.
2. One 240-kc full duplex communication channel which provides the following capabilities by use of frequency multiplex.
   a. Full duplex teletype: 6 circuits.
   b. Simplex voice circuits (2 wire with signaling): 2 circuits.
   c. Full duplex voice/data circuit (4 wire with signaling): 2 circuits.

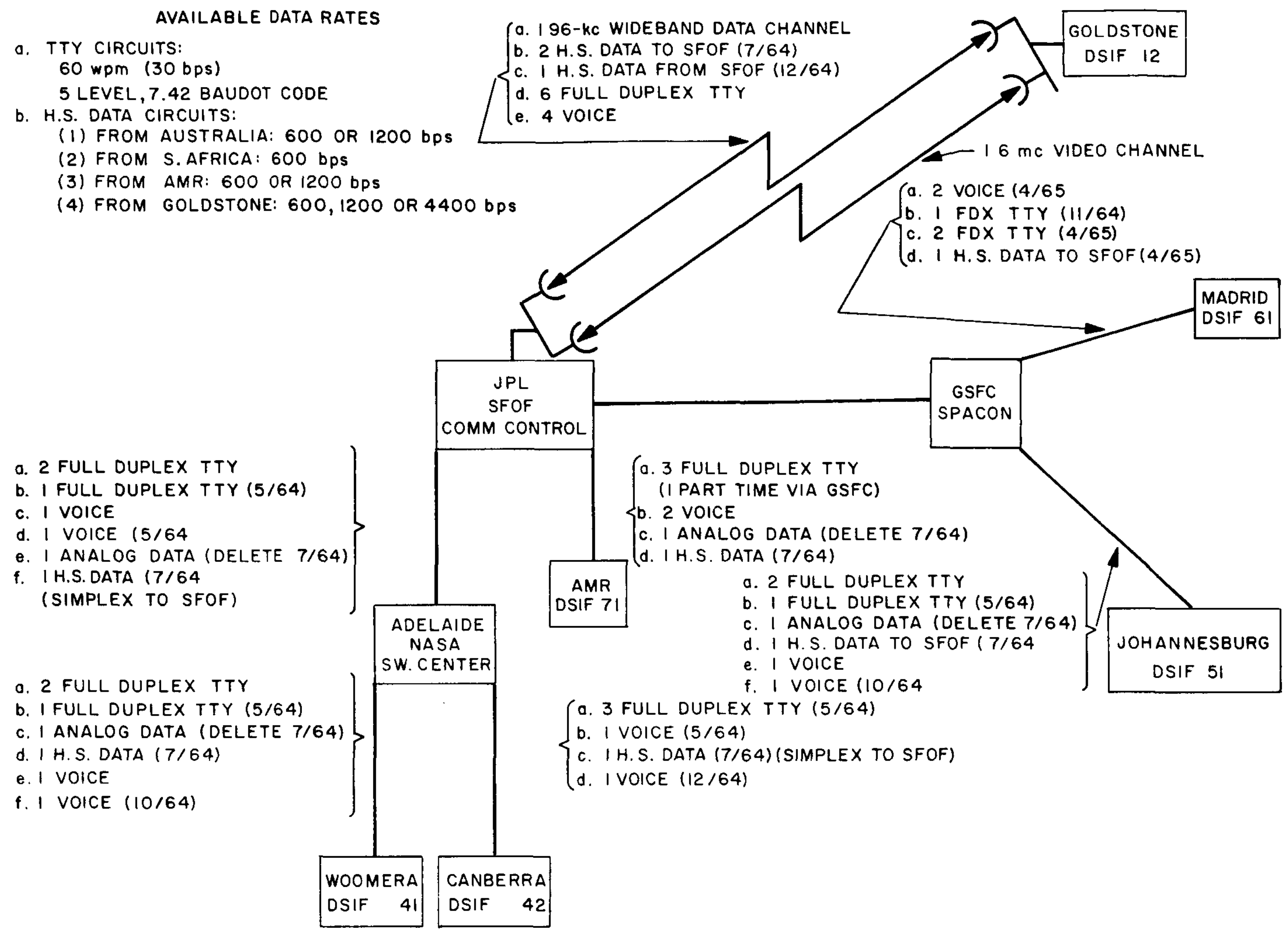


Fig. 26. Interstation communication circuits

d. Full duplex voice/data circuit (4 wire without signaling): 3 circuits.

e. 3-kc data circuit for 600 or 1200 bit/sec data transmission: 1 circuit, Goldstone to JPL only.

f. 6-kc full duplex data circuits for analog data: 2 circuits.

g. 96-kc full duplex data circuit for analog data: 1 circuit.

C. DSIF Subsystem Characteristics

1. Antennas and Feeds

The antennas are parabolic reflectors operating without radomes. The 85-ft antennas use polar (equatorial) mounts while the 210-ft antennas use Az-El mounts. A cassegrain feed system is used on all antennas, the low-noise preamplifier being mounted in the cassegrain cone assembly. The transmitter final amplifiers and the input section of the receiver are located in cages mounted on the back of the reflector structure. The acquisition aid antenna and the optical package (TV camera, film camera, and optical telescope) are also mounted on the reflector.

a. System temperature. Figure 27 shows the antenna sky temperatures at 2388 Mc as measured at Goldstone with an 85-ft antenna. At 2295 Mc the system noise temperature with a parametric amplifier is 270 $\pm$50°K, and with a traveling wave maser will be 55 $\pm$10°K. These noise temperatures include the quiet sky, antenna, feed line, diplexer, switches, preamplifiers and receiver.

b. DSIF antenna reflectors. The existing and proposed antenna reflectors are shown in Table 8.

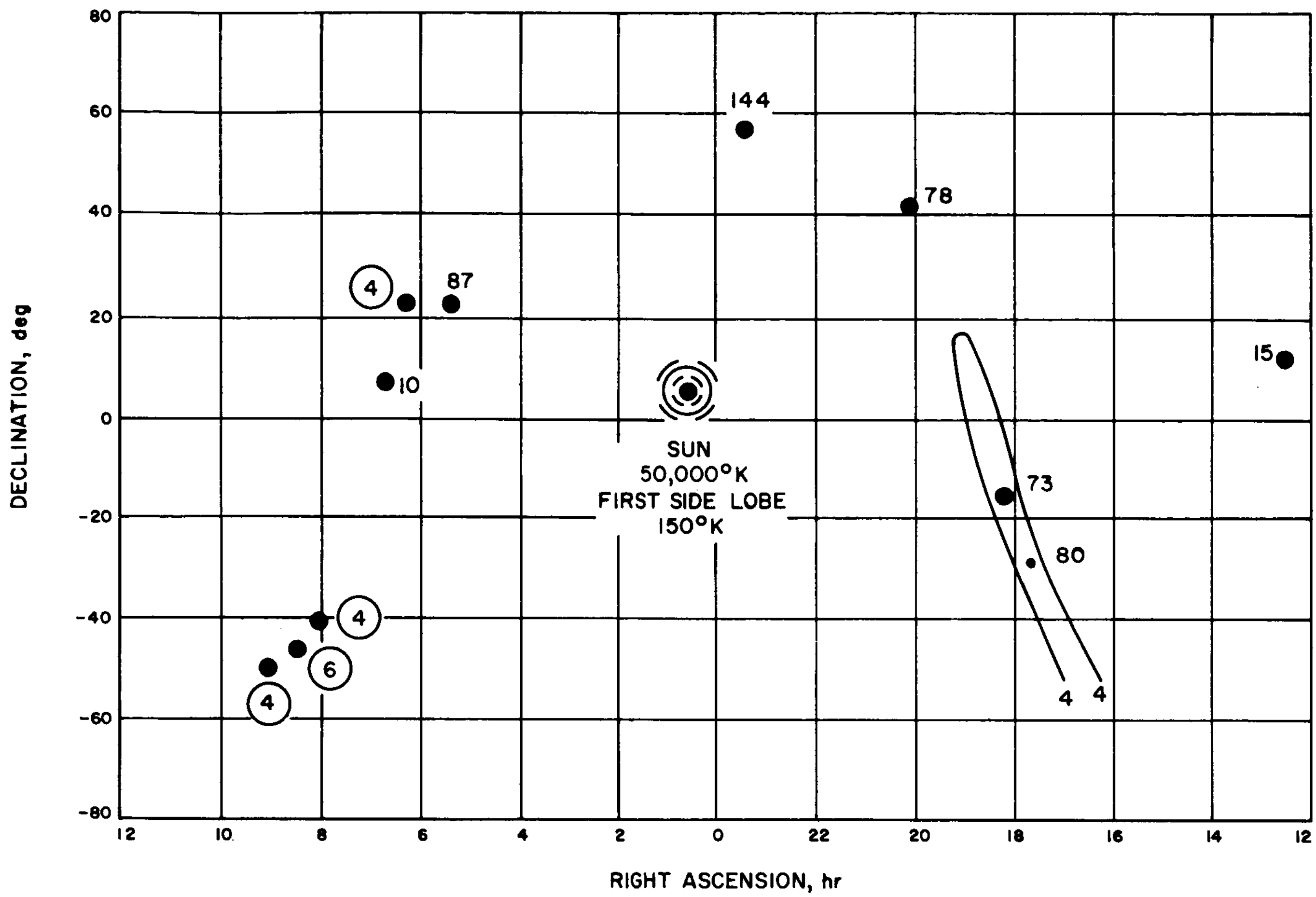


Fig. 27. Antenna sky temperature at 2388 Mc

Table 8. DSIF existing and programmed antennas

	Antenna diameter, ft					Antenna diameter, ft			
	6[a]	85	85	210		6[a]	85	85	210
Mount	—	Az-El	Polar	Az-El	Year operational				
Pointing accuracy,[b] deg	—	0.01–0.02	0.01–0.02	0.02[c]	Goldstone, Mars				(A)Jan 1966
Max angular rate, deg/sec	—	2.0	0.7	0.5[c]	Woomera			(I)	
Year operational					Canberra			(A)1965	(P)1967
Goldstone, Pioneer			(I)		Johannesburg			(I)	
Goldstone, Echo			(I)		Madrid			(A)1965	(P)1967
Goldstone, Venus		(I)[d]			Spacecraft monitoring	(I)			

A: authorized. I: installed. P: proposed.

[a]Present size of L-band antenna (temporary). Diameter of the permanent S-band antenna not determined; will probably be from 10 to 30 feet and will be installed in 1965(A).

[b]The capability of pointing the radio beam in a specified direction within a specified rms error is defined as the pointing accuracy.

[c]Design goal.

[d]For engineering and development work. Not generally available for operational use.

c. DSIF antenna feeds. The antenna feeds listed in Table 9 are planned for specific program support. As a general rule, tracking and transmitter feeds are righthand circularly polarized (IEEE standard). Tracking feeds utilized are exclusively of the simultaneous-lobing type.

2. GSDS Transmitters

Transmitter capability is incorporated in the DSIF for the purpose of providing two-way doppler data and command and control of the spacecraft. Depending on the particular mission, power outputs from 25 w to 10 kw CW are available. A 100-kw transmitter is installed on the R&D 85-ft antenna at the Goldstone *Venus* site and under certain conditions may be made available for operational use. The transmitters have a phase-modulation capability and are excited with either a voltage-controlled oscillator or a frequency synthesizer whose source frequency is the station frequency and time standard oscillators. Diplexed operation with transmitter

Table 9. DSIF programmed feed capability

	Frequency, Mc			
	2295/2115	2115	2295	2295/2115
Feed Type[a]	T/T	transmit	listen	L/T
Feed Location[b]	cass	cass	cass	FP
Output power capability, kw	10	100	—	.025
Antenna diameter, ft	85	85	210	e
Gain, transmit, db	51	51	—	
Gain, track or listen, db	53	—	61	e
Feed line loss,[c] db	0.4	0.4	0.2	e
Polarization[d]	LCP or RCP	LCP or RCP	LCP or RCP	e
Beamwidth, deg	0.35	0.35	0.1	e
Station and operational date				
11 Goldstone, Pioneer	(A)May 1964			
12 Goldstone, Echo	(A)June 1965			
13 Goldstone, Venus		(I)		
14 Goldstone, Mars			(A)Jan 1966	
41 Woomera	(A)Sept 1964			
42 Canberra	(A)Jan 1965		(P)1967	
51 Johannesburg	(A)Sept 1964			
61 Madrid	(A)June 1965		(P)1967	
71 Spacecraft monitor				(A)May 1965

A: authorized. I: installed. P: proposed.

[a]T/T = Track and transmit with diplexer; L/T = listen and transmit with diplexer.

[b]Cass = cassegrain cone; FP = focal point.

[c]Indicated loss is not included in antenna gain.

[d]LCP = left-hand circular polarization; RCP = right-hand circular polarization.

[e]Antenna diameter not determined; will probably be 10 to 30 ft.

Table 10. DSIF programmed transmitter capability

Frequency, Mc	2115	2115	2115
Power output, w	25	10K	100K[a]
Station operational date			
Goldstone, Pioneer		(A)May 1964	
Goldstone, Echo		(A)June 1965	
Goldstone, Venus			(I)
Goldstone, Mars			
Woomera		(A)Sept 1964	
Canberra		(A)Jan 1965	
Johannesburg		(A)Sept 1964	
Madrid		(A)June 1965	
Spacecraft monitoring	(A)May 1965		

A: authorized. I: installed.

[a]R&D facility; not normally available for operations.

powers up to 10 kw and with a receiver operating at a different frequency is employed. Table 10 indicates the planned future transmitter capability.

3. GSDS Receivers

The DSIF stations incorporate extremely sensitive and stable receivers which are designed to track the phase of the received RF carrier and to detect both amplitude and phase modulation. The receiver listed in Table 11 consists of a low-noise preselector mixer, carrier and sideband IF amplifiers, detectors, and a voltage-controlled local oscillator, the combination comprising a double conversion superheterodyne automatic-phase-tracking receiver. Doppler data are derived from the local oscillator signal, telemetry data from a separate detection channel, and angle error data from separate angle-error detection channels.

Each station has two reference channels, two angle error detection channels for the 85-ft antenna, and two angle channels for the acquisition aid antenna.

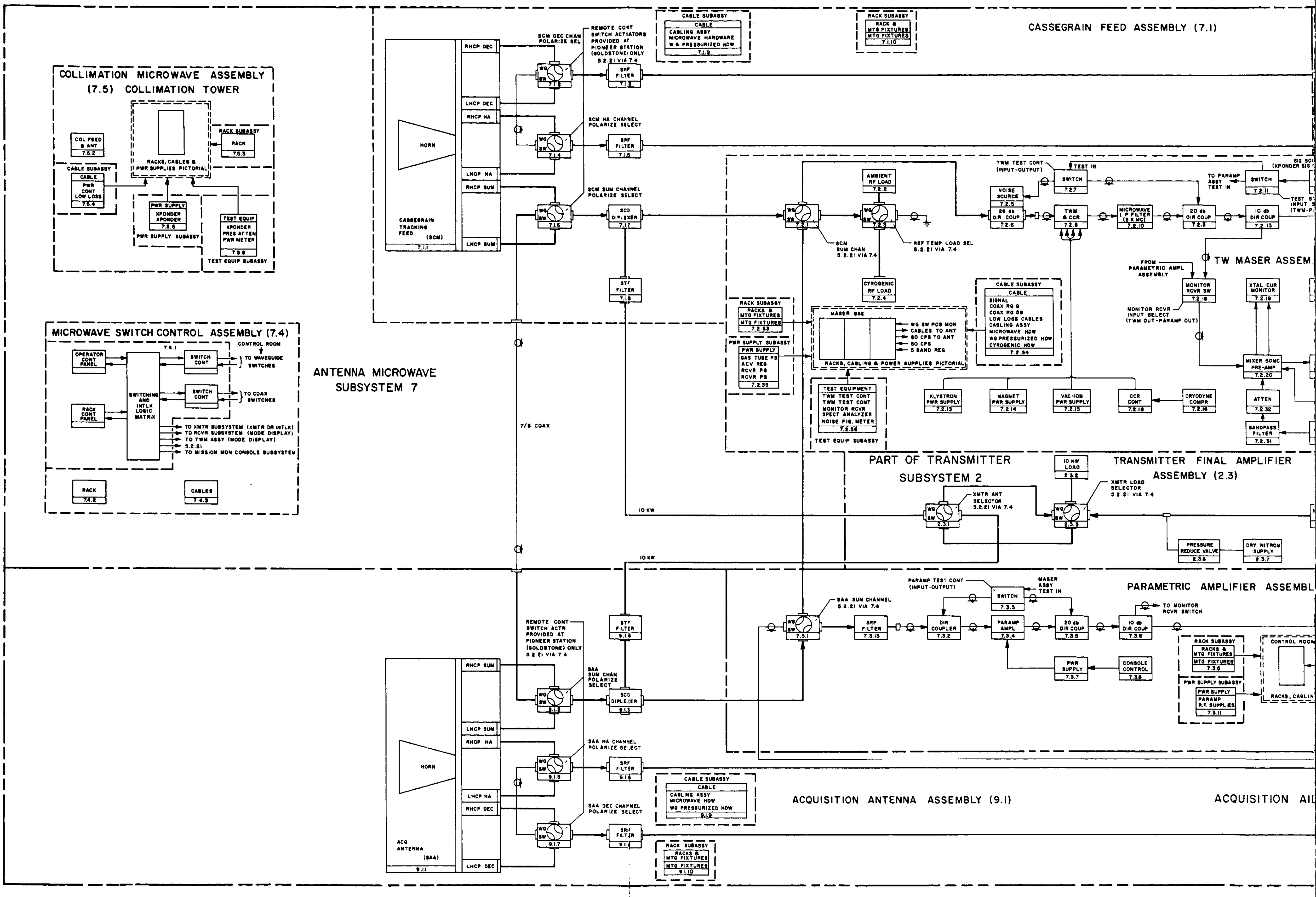
4. Typical DSIF RF System

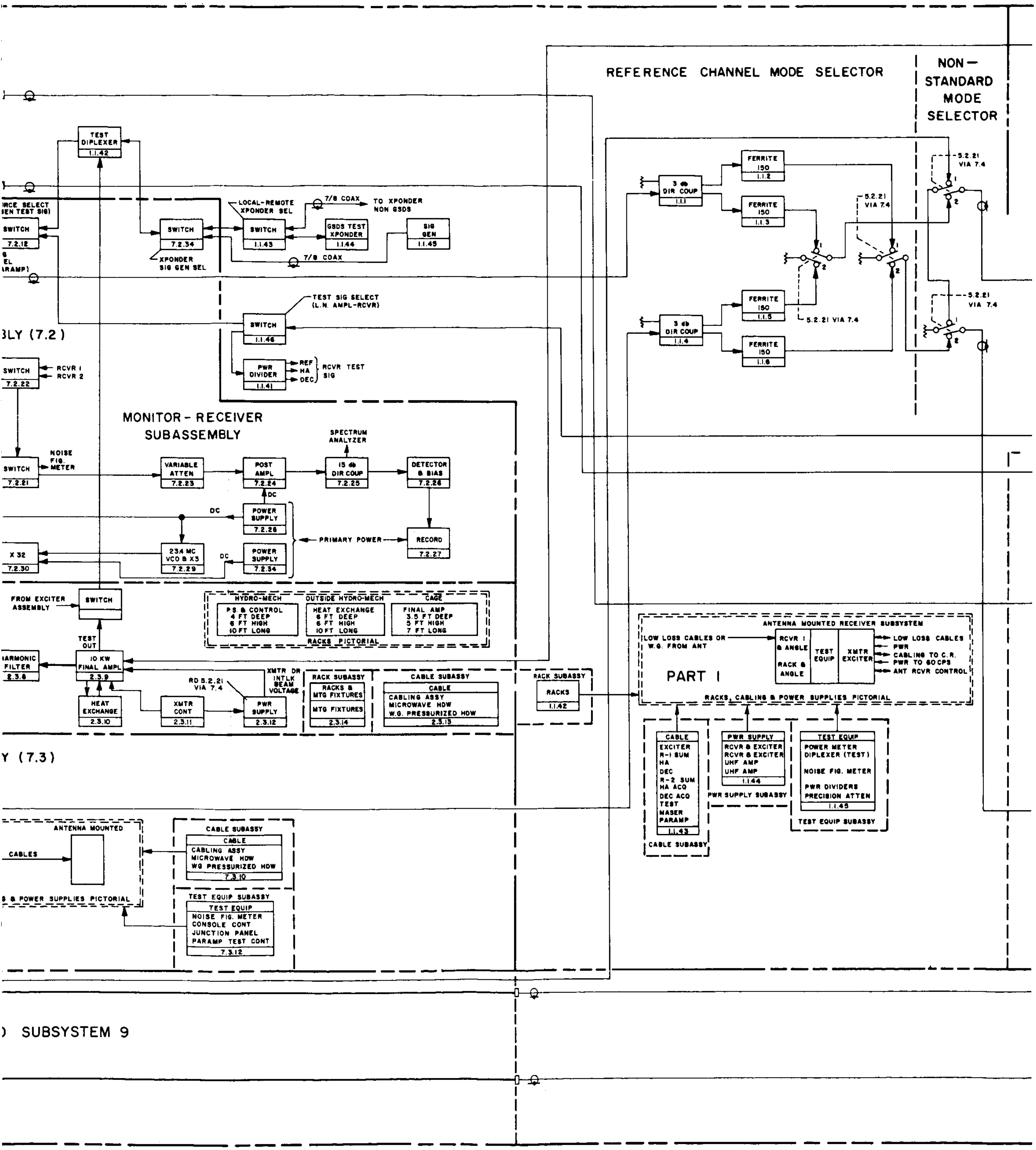
A typical DSIF tracking and communications system embodying all of the capabilities discussed above appears in Fig. 28.

Table 11. DSIF programmed receiver capabilities

	S-band
Nominal center frequency, Mc	2295 ±5
Automatic frequency tracking range	
Strong signal levels, kc	±67
Threshold signal levels (6-deg phase error), kc	±2.3
Automatic-phase-control effective noise bandwidth at threshold, cps	12, 48, or 152 $^{+0}_{-10}$ %
Automatic-phase-control effective noise bandwidth strong signals, cps	120, 255, or 500 $^{+0}_{-10}$ %
Effective system noise temperature[a]	
Parametric preamplifier, °K	270 ±50
Maser, °K	55 ±10
Threshold carrier level (level below which phase lock cannot be maintained) BW = 12 cps	
Parametric amplifier, dbm	−163.5
Maser amplifier, dbm	−170.4
Maximum frequency tracking rate BW = 12 cps	
Strong signal level (30 deg phase error), cpsps	150
Threshold signal level (6 deg phase error), cpsps	4
Dynamic signal level range, from threshold to:	
Receiver, dbm	−60
Maser or parametric, dbm	−80
Intermediate frequencies	
First, Mc	50
Second, Mc	10
Intermediate frequency amplifier half power bandwidths	
First, Mc	10
Second, Mc	3.33

[a]Includes receiver, transmission line, feed and antenna pointing at quiet sky.


CASSEGRAIN FEED ASSEMBLY (7.1)
COLLIMATION MICROWAVE ASSEMBLY (7.5) COLLIMATION TOWER
MICROWAVE SWITCH CONTROL ASSEMBLY (7.4)
ANTENNA MICROWAVE SUBSYSTEM 7
TW MASER ASSEM
PART OF TRANSMITTER SUBSYSTEM 2
TRANSMITTER FINAL AMPLIFIER ASSEMBLY (2.3)
PARAMETRIC AMPLIFIER ASSEMBL
ACQUISITION ANTENNA ASSEMBLY (9.1)
ACQUISITION AI
HORN
7/8 COAX
10 KW


REFERENCE CHANNEL MODE SELECTOR
NON-STANDARD MODE SELECTOR
TEST DIPLEXER 1.1.42
LOCAL-REMOTE XPONDER SEL
7/8 COAX
TO XPONDER NON GSDS
SWITCH 7.2.34
SWITCH 1.1.43
GSDS TEST XPONDER 1.1.44
SIG GEN 1.1.45
XPONDER SIG GEN SEL
TEST SIG SELECT (L.N. AMPL-RCVR)
SWITCH 1.1.46
PWR DIVIDER 1.1.41
REF
HA
DEC
RCVR TEST SIG
3 db DIR COUP 1.1.1
3 db DIR COUP 1.1.4
FERRITE 150 1.1.2
FERRITE 150 1.1.3
FERRITE 150 1.1.5
FERRITE 150 1.1.6
5.2.21 VIA 7.4
MONITOR-RECEIVER SUBASSEMBLY
SPECTRUM ANALYZER
VARIABLE ATTEN 7.2.23
POST AMPL 7.2.24
15 db DIR COUP 7.2.25
DETECTOR & BIAS 7.2.26
POWER SUPPLY 7.2.28
POWER SUPPLY 7.2.34
234 MC VCO & X3 7.2.29
RECORD 7.2.27
PRIMARY POWER
DC
SWITCH 7.2.12
SWITCH 7.2.22
RCVR 1
RCVR 2
SWITCH 7.2.21
NOISE FIG. METER
X 32 7.2.30
BLY (7.2)
FROM EXCITER ASSEMBLY
SWITCH
TEST OUT
HARMONIC FILTER 2.3.8
10 KW FINAL AMPL 2.3.9
HEAT EXCHANGE 2.3.10
XMTR CONT 2.3.11
PWR SUPPLY 2.3.12
RD 5.2.21 VIA 7.4
XMTR DR INTLK BEAM VOLTAGE
HYDRO-MECH
P.S. & CONTROL 4 FT DEEP 6 FT HIGH 10 FT LONG
OUTSIDE HYDRO-MECH
HEAT EXCHANGE 6 FT DEEP 6 FT HIGH 10 FT LONG
CAGE
FINAL AMP 3.5 FT DEEP 5 FT HIGH 7 FT LONG
RACKS PICTORIAL
RACK SUBASSY
RACKS & MTG FIXTURES
MTG FIXTURES
2.3.14
CABLE SUBASSY
CABLE
CABLING ASSY
MICROWAVE HDW
W.G. PRESSURIZED HDW
2.3.15
RACK SUBASSY
RACKS 1.1.42
ANTENNA MOUNTED RECEIVER SUBSYSTEM
LOW LOSS CABLES OR W.G. FROM ANT
RCVR 1 & ANGLE
TEST EQUIP
XMTR EXCITER
RACK & ANGLE
LOW LOSS CABLES
PWR
CABLING TO C.R.
PWR TO 60 CPS
ANT RCVR CONTROL
PART I
RACKS, CABLING & POWER SUPPLIES PICTORIAL
CABLE
EXCITER
R-1 SUM
HA
DEC
R-2 SUM
HA ACQ
DEC ACQ
TEST
MASER
PARAMP
1.1.43
CABLE SUBASSY
PWR SUPPLY
RCVR & EXCITER
RCVR & EXCITER
UHF AMP
UHF AMP
1.1.44
PWR SUPPLY SUBASSY
TEST EQUIP
POWER METER
DIPLEXER (TEST)
NOISE FIG. METER
PWR DIVIDERS
PRECISION ATTEN
1.1.45
TEST EQUIP SUBASSY
Y (7.3)
ANTENNA MOUNTED
CABLES
S & POWER SUPPLIES PICTORIAL
CABLE SUBASSY
CABLE
CABLING ASSY
MICROWAVE HDW
WG PRESSURIZED HDW
7.3.10
TEST EQUIP SUBASSY
TEST EQUIP
NOISE FIG. METER
CONSOLE CONT
JUNCTION PANEL
PARAMP TEST CONT
7.3.12
) SUBSYSTEM 9

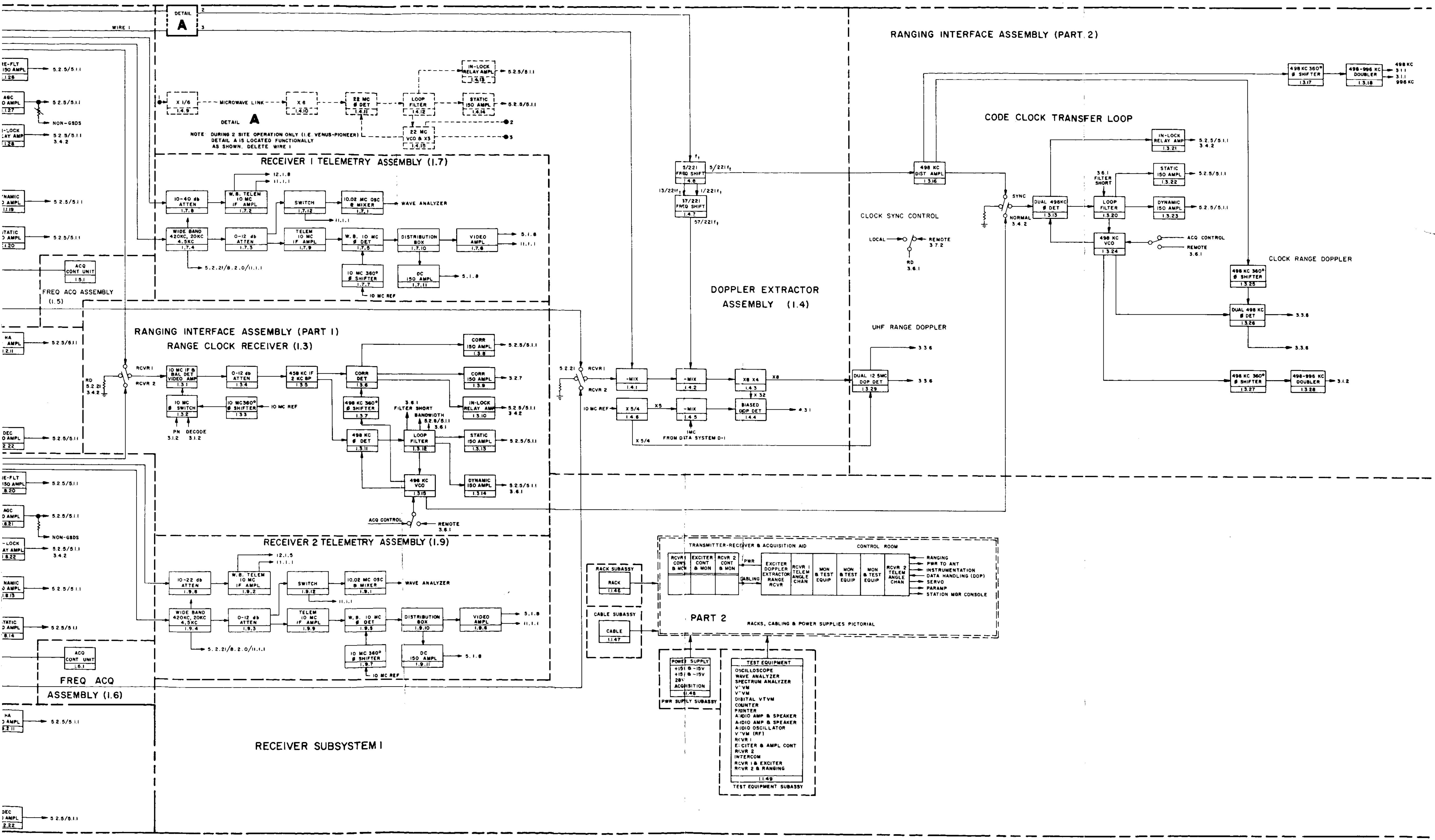


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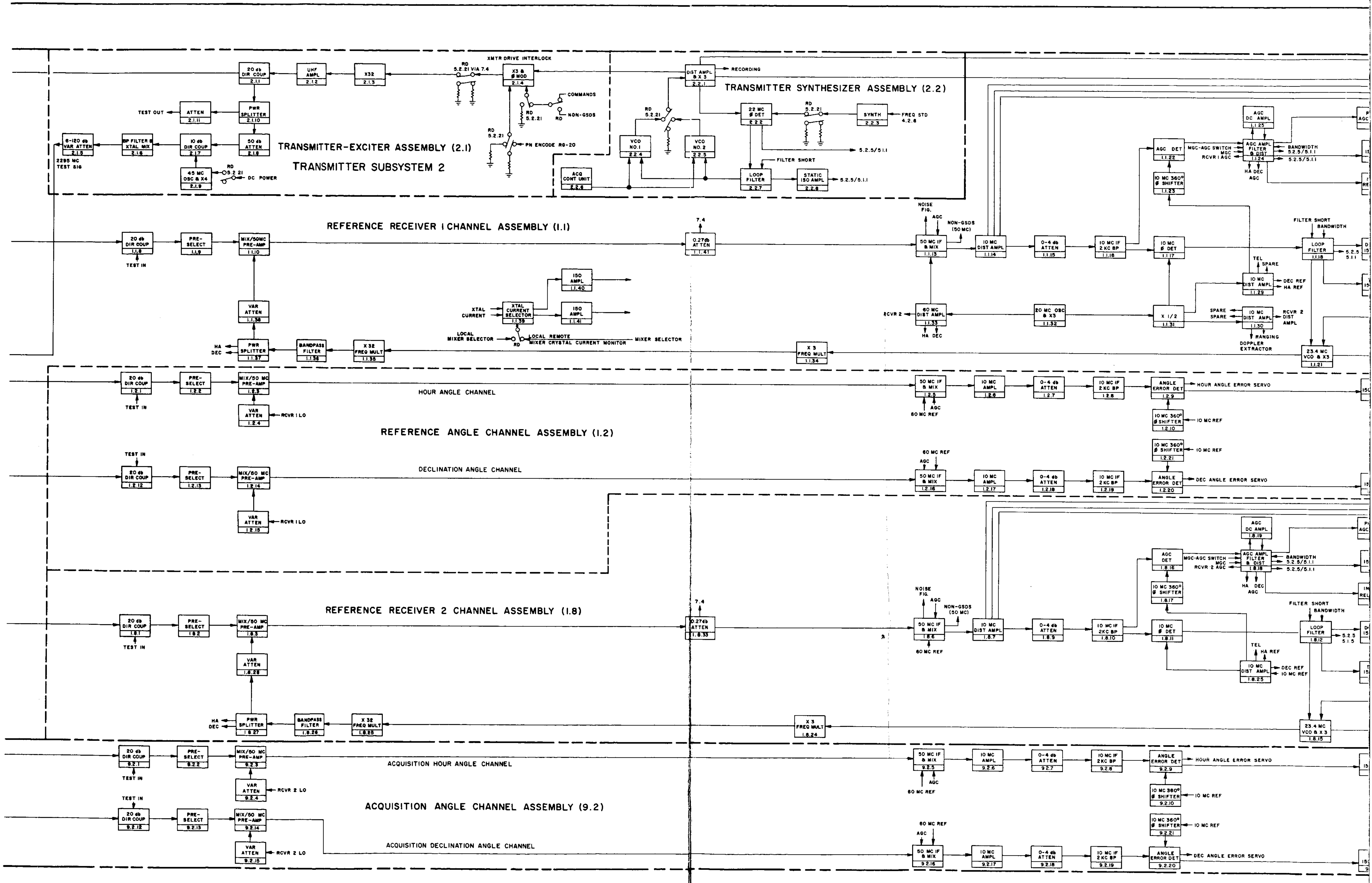
Fig. 28. DSIF tracking and communications system, block diagram



TRANSMITTER-EXCITER ASSEMBLY (2.1)
TRANSMITTER SUBSYSTEM 2
TRANSMITTER SYNTHESIZER ASSEMBLY (2.2)
REFERENCE RECEIVER I CHANNEL ASSEMBLY (1.1)
REFERENCE ANGLE CHANNEL ASSEMBLY (1.2)
HOUR ANGLE CHANNEL
DECLINATION ANGLE CHANNEL
REFERENCE RECEIVER 2 CHANNEL ASSEMBLY (1.8)
ACQUISITION ANGLE CHANNEL ASSEMBLY (9.2)
ACQUISITION HOUR ANGLE CHANNEL
ACQUISITION DECLINATION ANGLE CHANNEL
XMTR DRIVE INTERLOCK
RECORDING
FILTER SHORT
BANDWIDTH
HOUR ANGLE ERROR SERVO
DEC ANGLE ERROR SERVO
MIXER SELECTOR
MIXER CRYSTAL CURRENT MONITOR
PN ENCODE RG-20
DOPPLER EXTRACTOR
2295 MC TEST SIG

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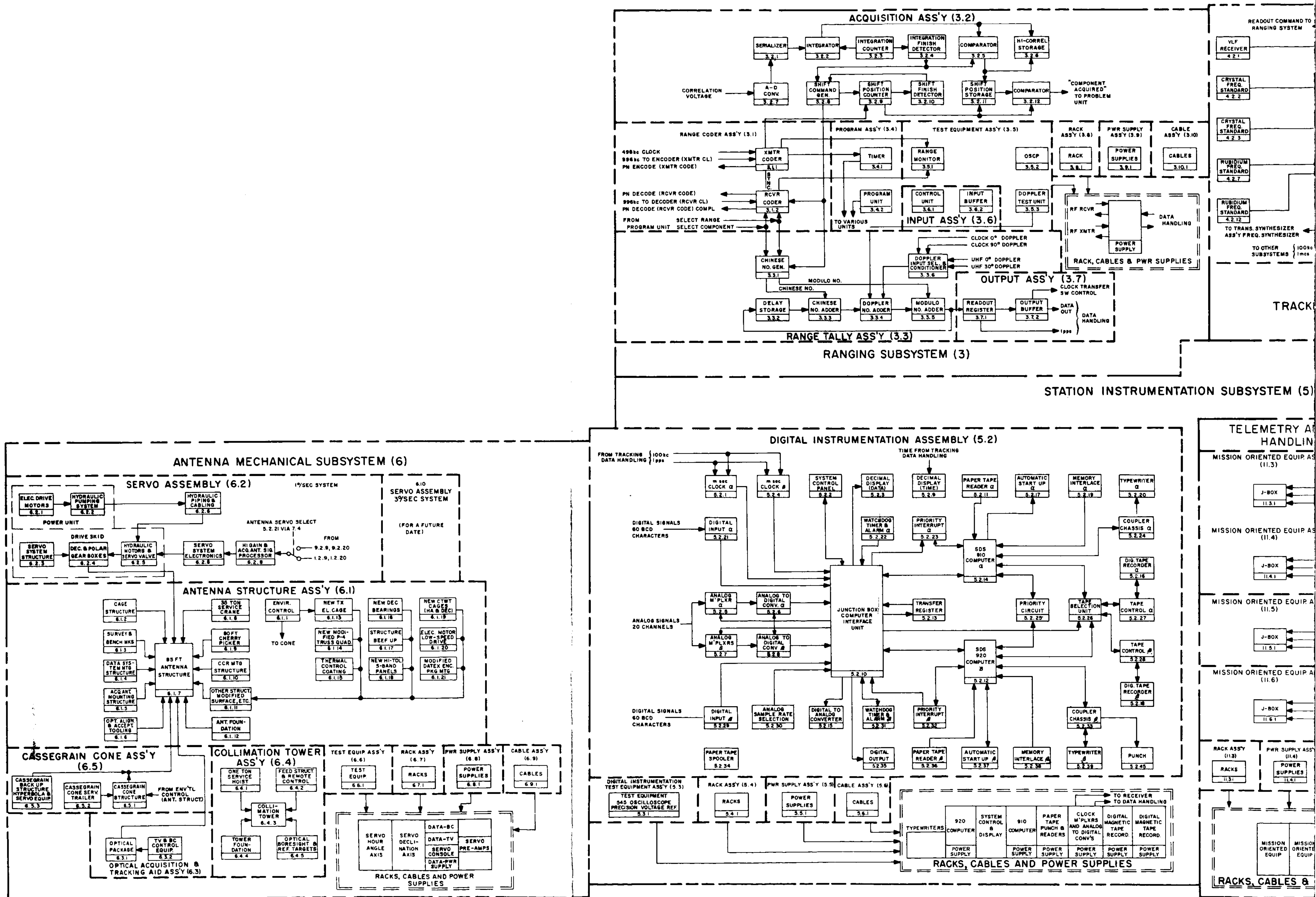

Fig. 28. DSIF tracking and communications system, block diagram (cont'd)

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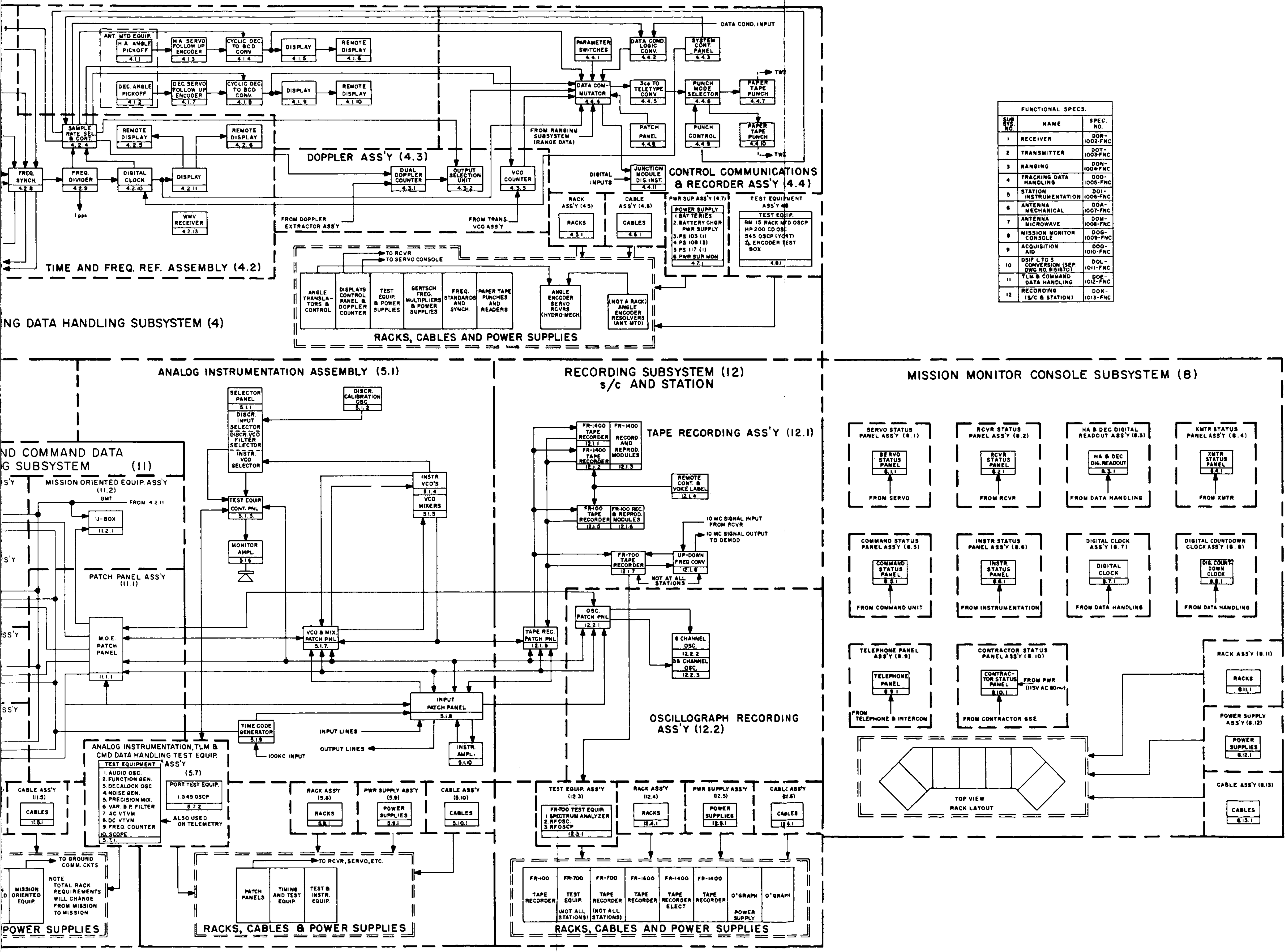

FUNCTIONAL SPECS.		
SUB SYS. NO.	NAME	SPEC. NO.
1	RECEIVER	DOR-1002-FNC
2	TRANSMITTER	DOT-1003-FNC
3	RANGING	DON-1004-FNC
4	TRACKING DATA HANDLING	DOD-1005-FNC
5	STATION INSTRUMENTATION	DOI-1006-FNC
6	ANTENNA MECHANICAL	DOA-1007-FNC
7	ANTENNA MICROWAVE	DOM-1008-FNC
8	MISSION MONITOR CONSOLE	DOG-1009-FNC
9	ACQUISITION AID	DOQ-1010-FNC
10	DSIF L TO S CONVERSION (SEP. DWG NO. 9151870)	DOL-1011-FNC
11	TLM & COMMAND DATA HANDLING	DOE-1012-FNC
12	RECORDING (S/C & STATION)	DOK-1013-FNC

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5. DSIF Acquisition Procedures

The DSIF acquisition procedures can be separated into six different functions, viz, pointing the antenna in the direction of the spacecraft, tuning and locking the receiver to the spacecraft transmitted frequency, locking the spacecraft receiver to the ground transmitted frequency, establishing range lock, synchronizing the telemetry demodulator and decommutator to the detected telemetered signal, and tuning and locking each phase-lock-loop discriminator to its channel frequency. It is necessary to perform the first two procedures before telemetry data and/or one-way doppler data are available, the first four procedures before range data are available, and the first three plus the fifth and/or the sixth procedures before specific telemetry information is available for station use or for transmission over the teleprinter circuits. Each procedure has certain minimum time requirements which together establish the shortest time in which it is possible for a DSIF station to make a complete acquisition of the spacecraft. This time at the present is about 1 min for the start of recording of telemetry and 4 min for the beginning of transmission by teleprinter of near real-time telemetry data. The maximum time may be much longer depending on circumstances; however, the normal range of time is from 1 to 10 min for start of recording and 4 to 16 min for the start of teleprinter transmission.

a. Antenna pointing. It is necessary that antenna pointing information be provided to each station *before* it is scheduled to acquire a spacecraft. Nominal ephemeris data are generally made available many days before the first acquisition is required, and it is corrected with actual data as soon as available. If corrected look angles are not made available for nonstandard trajectories, it is necessary for a station to start an area search procedure to enable it to acquire the spacecraft. To assist in this process the overseas stations are equipped with acquisition aid antennas. These antennas are mounted on the 85-ft antenna, have beamwidths of about 20 deg and are boresighted with the 85-ft antenna. They have simultaneous-lobing outputs which are connected to their own angle channel receivers. By observing the angle errors generated simultaneously by both the acquisition aid antenna receivers and the 85-ft antenna angle receivers, it is possible to make a smooth change from tracking with the acquisition aid antenna to tracking with the 85-ft antenna.

When good ephemeris data are available, the antenna can be pointed at a spacecraft in advance of acquisition, and no time is required to point the antenna. When it is necessary to use the acquisition aid antenna, the time required may vary from a few seconds to several minutes and is dependent upon angular antenna velocities and accelerations, signal-to-noise ratio, the a priori knowledge of transmitted frequency, and the skill of the operators.

b. Receiver tuning. Tuning of the receiver is accomplished by changing the voltage applied to a voltage-controlled oscillator (VCO) which feeds the first mixer. If good a priori information of the received frequency (including doppler) is available at the station and the signal level is at least 5 db above receiver threshold, carrier lock is usually accomplished in less than 1 min. If a frequency search has to be made and/or the signal level is less than 5 db above threshold, it may take several minutes before lock can be obtained. The range of frequencies over which the VCO may be controlled is adjustable by changing the crystal.

c. Transmitter tuning. Spacecraft for JPL-directed projects are designed to have a transponder with a non-tunable receiver and a coherent relationship between received and transmitted frequencies. In order for these receivers to lock onto a frequency transmitted from the ground, it is necessary to vary the ground transmitter frequency until the spacecraft receiver locks onto it. This can usually be determined by a telemetry reading of the spacecraft receiver AGC voltage. The moment of establishment of spacecraft receiver lock sometimes can be determined by a loss of lock of the ground receiver. Where a priori information on the spacecraft receiver frequency is known and the range to the spacecraft is relatively short, two-way lock is usually accomplished in less than a minute. For greater ranges, the round-trip transmission time and the signal-to-noise ratio at the spacecraft receiver become the controlling factors and acquisition may require many minutes.

The frequency of the transmitter exciter is controlled either by a VCO, whose bands of controllable frequencies are changed by replacing a crystal, or by a frequency synthesizer.

d. Ranging. After two-way lock has been obtained, range measurements may be made. This is accomplished by phase-modulating the ground transmitter frequency with a coded signal which is generated by a pseudorandom binary code generator. This signal, as received by the ground receiver after having been received by the spacecraft transponder and retransmitted to the ground, is phase-compared with a delayed identical pseudorandom code generated at the receiver. After synchronization is accomplished, the delay time required for two-way transmission, and hence the range, is kept track of by the range tally. Once range acquisition is accomplished, the code modulation may be turned off. The range measurement is kept current by continuously tallying the doppler obtained from a submultiple of the carrier frequency. The range tally is periodically read out to a range register as demanded by the data handling equipment.

After resetting the range tally and readout registers to zero and locking up the clock-frequency phase lock loop, the equipment automatically performs the various functions of making a range measurement. One of these functions is sampling the correlation voltage. The number of possible samples per measurement and the time required to make this number of samples are shown in the following table:

Number of Samples	*Time Required*
2^0	29 millisec
2^4	460 millisec
2^6	1.84 sec
2^7	3.7 sec
2^8	7.4 sec
2^9	14.7 sec
2^{10}	29.4 sec
2^{11}	58.8 sec
2^{12}	1.97 min
2^{13}	3.92 min
2^{14}	7.84 min
2^{15}	15.7 min
2^{16}	31.3 min
2^{17}	1.05 hr
2^{18}	2.10 hr
2^{19}	4.20 hr

With strong signals the number of samples can be quite small, while with noisy signals many samples must be taken. It is expected that with clean signals the number of samples will be 2^6 or less, while with quite noisy samples no more than 2^{12} samples will be required. It is estimated that the time required to reset the tally and register and to lock the clock loop will be 30 sec or less, and thus the total range acquisition time should be between 30 sec and 2.5 min.

*e. **Telemetry demodulation and decommutation.*** If the communications system design is digital, a special demodulator and decommutator are generally required at each station for near real-time transmission of telemetry information to the operations center and for station operations use. Normally this equipment is automatic in operation, and the acquisition time is dependent upon the speed of operation of the automatic circuits in establishing synchronization between the coded synchronization signal and the telemetry signal. It is also normal to have the output of the demodulator feed the teleprinter encoder directly so that the acquisition time is dependent only on the demodulator. The decommutator is essentially an off-line unit, and its outputs are used for station operations where the acquisition time is not a critical item.

Using the *Mariner* communication system as an example, at 8-⅓ bits/sec the mean time for acquisition by the demodulator for a single correlation is 3 min, with a maximum time of 6 min. These same times are required for each additional correlation. At higher bit rates the time is decreased in direct proportion to the increase in bit rate.

The acquisition time of the decommutator is dependent upon the mode of operation of the spacecraft, the bit rate, and the frame length. The maximum acquisition time occurs when the spacecraft is in the cruise mode, and both scientific and engineering data are being transmitted at the lowest bit rate of 8-⅓ bits/sec. In this case the maximum acquisition time is 10 min for a single correlation.

*f. **Discriminators.*** If the communications system design is FM/PM using subcarrier frequencies to carry either digital or analog data, phase lock discriminators are used to extract the data from each subcarrier. The time required to lock a discriminator onto its subcarrier is similar to the tuning of a receiver and is dependent upon signal strength and operator experience. With good signals this time should be about 10 to 20 sec per discriminator.

D. Testing and Checkout

Station preparation times vary with mission requirements. However, once the equipment is installed and operating, the station can be made operational in approximately one week. Thereafter, 3 hr per day are needed for routine checkout and calibration, and approximately 1 hr is needed for postcalibration checks after each tracking and data acquisition mission. A period of at least 8 hr is required every 3 days for routine maintenance.

Currently, most checkouts, calibrations, and tests are performed manually. However, as new equipment is developed for the DSIF, consideration is being given to automating its operations as much as possible consistent with the maintenance of high reliability. Eventually it is hoped that the time required for calibrations and checkout will be considerably reduced.

IV. DSIF RELATIONSHIPS

A. Space Flight Operations Facility

The Space Flight Operations Facility (SFOF) is located at JPL in Pasadena, California. This facility consists of a three-story building which houses the operations control centers, data displays, control consoles, digital computers and associated input/output equipment, data reduction equipment, and the communications center, and provides areas for scientific and engineering spacecraft data analysis teams. It has facilities for the reception and reduction of tracking data, the generation of trajectory, prediction, acquisition and command information, and the reduction of telemetry data for use by cognizant engineering and scientific experimenters. The DSIF operations control center is located in this building adjacent to the spacecraft operations control centers. The facility is equipped to provide simultaneous operations control over two spacecraft and monitoring control simultaneously over four spacecraft. It is a mission-independent unit which is designed to work with the DSIF to furnish a complete operations, tracking, command, data acquisition, and data processing system for use with deep space probes. Special-purpose equipment required by a particular project can be installed in the DSIF and the SFOF.

B. Foreign Governments and Operating Agencies

The overseas stations of the DSIF are subject to agreements between the United States Government and the governments of the countries in which the stations are located. In general, these agreements specify that the United States shall finance, construct, and install the entire facility, but that the completed station shall be staffed, operated, and maintained by the local government or its appointed agency. The agency in turn usually appoints a station manager who bears the full responsibility for the station. JPL provides a resident engineer who acts as the official liaison between the foreign operating agency and JPL. The JPL resident engineer has no operational authority; he merely assists the agency's station manager in a staff capacity.

The foregoing relationships become important when a project office or its prime contractor desires to add special support equipment and United States personnel to the overseas sites for particular missions. The support group personnel must realize that they are guests of the country in which the station is located, and that the project service they perform must not conflict with either the responsibility or the authority of the operating agency or its station manager. For this reason, any and all plans for the addition of equipment or personnel to the overseas sites must be coordinated with, and controlled by, the DSIF and the DSN.

C. NASA Project Offices

The DSN is operated by JPL under contract to NASA for the support of NASA's deep space exploration programs. It will be used for all JPL assigned programs and for other NASA programs which require this type of facility. When necessary and where the schedule allows it, the DSIF, SFOF, or the communications network may be used singly on other projects.

Project offices can request the support of the DSN or its components in accordance with procedures established by the NASA Management Manual TS-205.

D. Other Networks

Working relationships have been established between the DSN and AMR covering the launch and postinjection tracking of various unmanned spacecraft. In essence, the downrange tracking facilities of AMR maintain communications contact and track the spacecraft as long as the vehicle is within the range of the AMR equipment. The downrange tracking data are sent back to the Cape and thence to a central computer which determines the initial trajectory of the spacecraft. Prediction data in the form of pointing angles, etc., are sent to the SFOF for distribution to the individual Deep Space Stations. The time sequence of the above process makes prediction data marginally available for the first pass over the DSIF stations. Consequently, the Johannesburg, Woomera, and Canberra stations are equipped with acquisition antennas to aid them to acquire the spacecraft on its first pass.

These same relationships are available for use by any project or mission, manned or unmanned, which has scheduled the support of the DSN for that project. Similar relationships will be made with other networks which may be used in conjunction with the DSN in support of a project. Normally, other networks would be used for communication with a spacecraft which is near the Earth, while the DSN would be used for communication with the spacecraft when it is far from the Earth. The actual distances would depend upon mission requirements and trajectory parameters.

E. Commercial Contractors

All contractor-supplied equipment must be compatible (electrically, mechanically, functionally, and operationally) with the DSIF, must operate in the environments existing at the stations, and must not interfere with normal operations. The equipment must be given sufficient isolation so that it will not adversely affect the performance of station equipment, and it is desirable that it be capable of quick connect and disconnect. Normally the DSIF will be able to supply space in air-conditioned buildings for contractor and special-purpose equipment (see Section II).

The following specifications have been issued as guides to prospective contractors and may be obtained from JPL:

DOO-1022-GEN	General Specification DSIF Drawing Documentation Requirements
DOO-1023-DTL	DSIF Requirements for Contractor Preparation of Technical Manuals
8900A	Environmental Specification, DSIF Ground Equipment, Assembly Level Test Requirements
8905B	RF Equipment Preferred Components Lists for DSIF Equipment
8906A	General Requirements for DSIF General Specification GSDS Standard Modules
8907A	General Requirements for DSIF General Specification, DSIF Electronic Equipment

1. Contractor Responsibility

In furnishing equipment to a Deep Space Station, the contractor is normally responsible for its proper installation, checkout, maintenance, preflight operation, and the instruction of DSIF personnel in its proper operation and maintenance. However, for certain projects, the contractor may also be required to maintain and operate his equipment during flight operations.

Since the facilities of the DSIF are scaled to the operation and maintenance of only the GSDS equipment, the contractor shall supply the articles needed by his personnel to install, check out, and maintain his equipment. This contractor-supplied material includes tools, test equipment and spares (other than operational spares specified below). In addition, the contractor shall arrange for the personal needs of his employees, which normally shall include offsite living quarters, transportation, supplies, etc. Under emergency conditions, contractor personnel will have access to station facilities and services, but owing to the limited nature of the station's capabilities these facilities and services cannot be arranged on a continuing basis.

2. Operating Spares

One set of operating spares shall be supplied with each set of contractor equipment. Type and quantity of these spares shall follow the philosophy given in JPL Specification 8907A. Storage space will be provided by the DSIF, but the spares will remain under the control of the contractor for the period during which he is responsible for maintenance of his equipment. The contractor shall notify the DSIF of the amount of storage space required at each DSIF station, and obtain approval of the allocation of the space well in advance of the arrival of the equipment.

APPENDIX A

Design Control Technique

In current spaceflight programs, tight control of the telecommunication system parameters is necessary for successful system management because the overall spacecraft design is not able to afford large, arbitrary safety factors in signal-to-noise ratio.

In order to handle the problems of complex spacecraft and ground systems and maintain a reliable estimate of the signal-to-noise ratio performance of the overall system, a simple but effective accounting technique has been devised.

As shown in Table A1, all of the parameters that contribute to the system performance are listed in the approximate order that one would find in tracing a signal through the system. In Table A1 each parameter is listed in terms of a nominal or design value and a tolerance band. The responsible engineer or agency is also given.

In assembling such a tabulation the following rules are applied:

1. The nominal value and tolerance for each parameter is attested to in writing by the cognizant engineer or agency.
2. Any arbitrary padding or use of safety factors within the nominal values is strictly forbidden.

Table A1. Telecommunication design control

Project: ***Mariner*****; Channel: Spacecraft to Earth; Mode: High gain, tracking, diplexed, maser**

No.	Parameter	Value	Tolerance	Source
1	Total transmitter power (10 w)	+40.0 dbm	±1.0 db	H.D.
2	Transmitting circuit loss	−1.5 db	±0.4 db	PC, HD
3	Transmitting antenna gain	+23.5 db	+0.3, −0.5 db	SB
4	Transmitting antenna pointing loss	−1.1 db	±1.0 db	IK
5	Space loss (at 2295 Mc; R = 2.46×10^8 km)	−267.5 db	—	
6	Polarization loss	(Included in Item 4)		
7	Receiving antenna gain	+53.0 db	+1.0, −0.5 db	JRH
8	Receiving antenna pointing loss	0	0	
9	Receiving circuit loss	−0.2 db	±0.1	JRH
10	Net circuit loss	−193.8 db	+2.8, −2.5 db	
11	Total received power	−153.8 dbm	+3.8, −3.5 db	
12	Receiver noise spectral density (N/B) (T System = 55 ± 10°K)	−181.2 dbm/cps	+0.7, −0.9 db	IK, JRH
13	Carrier modulation loss	−4.1 db	+0.7, −0.9 db	IK
14	Received carrier power	−157.9 dbm	+4.5, −4.4 db	
15	Carrier automatic phase control noise BW ($2B_{LO}$ = 12.0 cps)	+10.8 db • cps	+0.0, −0.5 db	JRH
	Carrier performance for telemetry			
16	Threshold SNR in $2B_{LO}$	+6.0 db	—	BDM
17	Threshold carrier power	−164.4 dbm	+0.7, −1.4 db	
18	Performance margin	+6.5 db	+5.9, −5.1 db	

3. If any arbitrary ignorance factors are necessary (such as an allowance for an unknown propagation medium) they are placed in the tolerances and appropriately labeled.

4. The tolerance band must account for variations due to manufacturing, measurement, adjustment, component instability, and environment during the space flight.

5. The threshold signal level is the signal level that results in a threshold signal-to-noise ratio in the effective noise bandwidth of the detector.

6. The threshold signal-to-noise ratio is that which results in the minimum acceptable output signal quality. It will depend not only on the type of detector being used but also on the type of signal that is applied to the detector and on how the output signal is to be used.

Such a telecommunication design control table as shown here indicates the performance for only one ground station, spacecraft mode, and range point. By computing the performance as a function of time—taking into account the spacecraft trajectory, attitude, and modes of operation—and plotting it as shown in Fig. A1, a useful picture of the overall system performance is obtained. The periods of acceptable, marginal, and unacceptable performance are readily seen for an entire mission.

The design control table technique has several advantages: First, it formalizes the accounting of system performance in a uniform manner that facilitates the comparison of competing systems. Second, it minimizes or eliminates hidden pads or safety factors and the resulting overdesign. Third, it standardizes a criterion for an adequate system design. Fourth, it readily indicates the least controlled parameters of the system (those with the largest tolerances) and hence the areas where

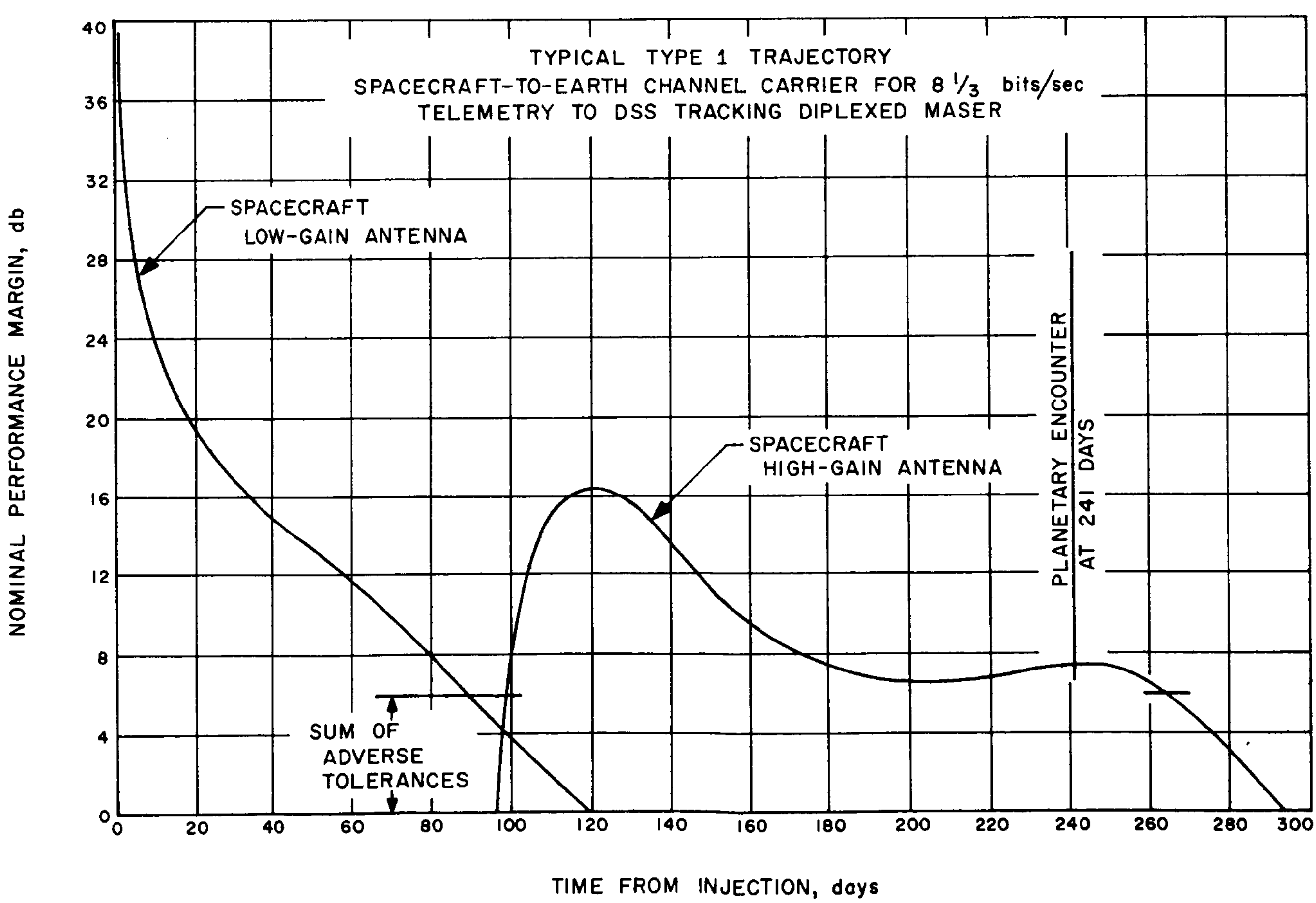

Fig. A1. Typical *Mariner* performance margin vs time

more knowledge and hardware improvement might be most profitable.

Using this tabulation (Table A1) the ratio of the nominal received signal level to the threshold signal level for each telecommunication function is computed (in db) and defined as the nominal performance margin. The linear sum of the parameter tolerances is used as the tolerance on this margin. For a system design to be considered adequate, experience has shown that it is adequate but not excessive design practice to require that the nominal performance margin be positive (in db) and equal to or greater than the magnitude of the adverse tolerance on the margin.

APPENDIX B

Characteristics of Recording Equipment

Table B1. FR-100c/1200 magnetic tape recorder

	Direct record/reproduce bandwidth, ±3 db and 25 db S/N
Tape speed, in./sec	
60	300 cps to 300 kc
30	150 cps to 150 kc
15	100 cps to 75 kc
7½	50 cps to 38 kc
3¾	50 cps to 19 kc
1⅞	50 cps to 10 kc
Flutter	0.43% PP at 60 in./sec
Input impedance	20,000 Ω
Output impedance	<50 Ω
Number of record modules	7
Number of reproduce modules	7

Number of recorders available per station: 1.
Number of channels per recorder: 7.
Tape size: 1/2 in. wide, 10-1/2- or 14-in. reels.
Electronic speed lock: not available.
FM record/reproduce: not available.
Digital record/reproduce: not available.

Table B2. FR-700-21 magnetic tape recorder (FR-800)

	Tape speed	
	12-1/2 in./sec	25 in./sec
Number of wide-band channels	1	2
Number of auxiliary channels	2	2
FM record/reproduce		
Frequency response wide-band channel, ±3 db	10 cps to 4 Mc	10 cps to 4 Mc
S/N db peak-to-peak signal to rms noise	30	30
Input and output signal level, volts peak	1	1
Input and output impedance, ohms unbalanced	50	50
Predetection direct record		
Frequency response wideband channel, ±3 db 5 Mc center	3.25 to 6.75 Mc	3.25 to 6.75 Mc
Input and output signal level, ±3 db dbm	10	10
Input and output impedance, ohms unbalanced	50	50
Direct record/reproduce		
Without multiplexer		
Frequency response auxiliary channel, ±3 db	300 cps to 15 kc	300 cps to 15 kc
S/N RMS signal to rms, noise db	30	30
Input and output level, volts RMS	1	1
Input impedance, ohms unbalanced	25,000	25,000
Output impedance (max); ohms unbalanced	600	600
With multiplexer (3 channel per track)		
Frequency response auxiliary channel, ±3 db	300 cps to 2.5 kc	300 cps to 2.5 kc
Input and output level, volts rms	1	1
Input impedance, ohms unbalanced	10,000	10,000
Output impedance (max), ohms unbalanced	600	600
Auxiliary Equipment		
Down Converter		
Input signal frequency, Mc	10 ±1.75	
Output signal frequency, Mc	5	
Input and output impedance, ohms unbalanced	50	
Input level, dbm	7 ±3 db	
Output level, dbm	10 min	
Up Converter		
Input signal frequency, Mc	5	
Output signal frequency, Mc	10 ±1.75	
Input and output impedance, ohms unbalanced	50	
Input and output level, dbm	10 ±3 db	
Number of recorders available per station: 1 Tape size: 2 in., 10-1/2-in. reel Electronic speed lock: Inherent in machine		

Table B3. FR-1400 magnetic tape recorder

Tape speed, in./sec	Direct record/reproduce		FM record/reproduce		Digital record/reproduce, (frequency shift keying)	
	3-db band width	db S/N	3-db frequency response	db S/N	bits/sec $\times 10^3$	bit error rate
120	400 cps to 1.5 Mc	20	dc to 500 kc	28	120	1 in 10^4
60	750 kc	19	250 kc		60	
30	375 kc	18	125 kc		30	
15	185 kc	17	62.5 kc		15	
7-1/2	95 kc	16	31 kc		7.5	
3-3/4	45 kc	15	15 kc		3.75	
Harmonic distortion	1% (or less), third harmonic for 1 kc recorded at 120 m/s		3% (or less)		not applicable	
Input level	0.25–25 v 1 v rms nominal		1.4–14 v peak to peak		0 ±0.5 = binary 0 −5 to −20 v = binary 1 or +5 to +20 v = binary 1	
Output level	0–2 v 1 v rms nominal		4 v peak to peak		0 ±0.5 v = binary 0 −10 v to −20 v = binary 1	
Input impedance	1 kilohm unbalanced		75 ohms unbalanced		1 kilohm	
Output impedance	30 ohms (or less) unbalanced		75 ohms unbalanced		100 ohms (or less)	
Linearity	not applicable		±1% of best straight line		not applicable	
Number of record modules	7 per recorder		4 per recorder		4 per recorder	
Number of reproduce modules	4 per recorder		2 per recorder		2 per recorder	

Number of recorders available per station: 2.
Number of channels per recorder: 7.
Tape size: 1/2-in. wide, 10-1/2 or 14-in. reels.
Electronic speed lock (JPL design): one system available for either recorder beginning late 1964.

Table B4. Oscillographs

	CEC 5-123 Optical	Sanborn 358-100 Heated Stylus
Number of recorders available per station	1	1
Number of channels per recorder	36	7 + 5 marker
Deflection for each channel, maximum peak to peak	6 in.	5 cm
Chart (paper) width, in.	12	12.5
Frequency response	dc to 90 cps $\pm 5\%$	dc to 125 cps ± 3 db
Input sensitivity signal channels, maximum	30×10^{-6} amp/in.	0.05 v/cm
Sensitivity adjustment signal channel, full scale	none	0.125 v to 250 v
Input sensitivity 4 marker channels	none	1.5 v at 0.5 ma
Input sensitivity 1 marker channel	none	contact closure
Input impedance (PP = peak to peak)	$\dfrac{\text{PP voltage}}{30 \times 10^{-6} \times \text{PP deflect}}$	500 K unbalanced
Chart speed	0.1, 0.4, 0.8, 1.6, 1,4,8,16,10,40,80, 160 in./sec	0.25, 0.5, 1.0, 2.5, 5,10,25,50, 100 mm/sec